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Performance Evaluation and Improvement of an Intersection - A Case Study of Thapathali Intersection

by

Lav Maharjan

A THESIS

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We, the undersigned, hereby confirm that we have thoroughly reviewed and recommended to the Institute of Engineering for approval a thesis titled "**Performance Evaluation and Improvement of an Intersection – A Case Study of Thapathali Intersection**" which has been submitted by **Lav Maharjan**. This submission is made in partial fulfillment of the requirements for the degree of Master of Science in Transportation Engineering.

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ABSTRACT

The Thapathali intersection located in Kathmandu Valley is a crucial junction connecting the city to Lalitpur and other major intersections like Maitighar and Tripureshwor. Given its high traffic volume, there is a need for a detailed analysis of the current operational performance of the intersection and the exploration of new solutions to improve its efficiency. A video-based survey was conducted over a period of 5 days including 3 weekdays and 2 weekends to gather data. The manual vehicle count was performed using custom manual counting software and the data was analyzed. The average peak hour traffic volume during the weekdays was 5,598 PCU in the morning and 4,886 PCU in the evening, while the weekend traffic volume was 4,697 PCU in the morning and 4,597 PCU in the evening. On average, motorcycles constituted 70.58% of the total traffic. The simulation model of the intersection was developed using the traffic analysis software SIDRA for both weekdays and weekends. After the models were calibrated and validated using the 95th percentile back of queue (BoQ), the performance of the intersection was evaluated under the current traffic policed controlled scenario. The analysis revealed average delays of 99.6 seconds/vehicle and 35.1 seconds/vehicle for weekdays and weekends respectively, with level of service (LoS) F and D under HCM 2010 and average speeds of 16.6 kmph and 24.7 kmph respectively. Seven alternative models were proposed for weekdays and weekends through lane reconfiguration and phasing and timing reconfiguration. The LC3-4P model was found to be the best option for both weekdays and weekends. The future performance of the intersection was evaluated for the time periods of 5 and 10 years, indicating that the weekday model will maintain LoS E till 2027 and the weekend model will maintain LoS E till 2032. It is recommended to perform a geometric upgradation of the intersection after 2032 with addition of flyover from Maitighar leg to Tripureshwor Leg along with pedestrian underpass so that the intersection operates under LoS of B during peak hour for both weekdays and weekends.

Keywords: Intersection, Peak hour volume, SIDRA, Passenger Car Unit (PCU), Back of Queue (BoQ), Delay, Level of Service (LoS), Performance Index (PI)

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LIST OF ABBREVIATIONS

ARRB: Australian Road Research Board

BoQ: Back of Queue

CSIR: Central Road Research Institute

CSV: Comma Separate Value

DoS: Degree of Saturation

DoTM: Department of Transport Management

FDOT: Florida Department of Transportation

HCM: Highway Capacity Manual

Indo-HCM: Indian Highway Capacity Manual

JICA: Japan International Cooperation Agency

KVITSP: Kathmandu Valley Intelligent Traffic System Project

LC: Lane Configuration

LoS: Level of Service

MOE: Measure of Effectiveness

OD: Origin-Destination

ORN: Overseas Road Note

PCU: Passenger Car Unit

PHF: Peak Hour Factor

PI: Performance Index

QGIS: Quantum Geographic Information System

RoW: Right of Way

SIDRA: Signalized (and un-signalized) Intersection Design and Research Aid

TIA: Traffic Intersection Analysis

USF: Unit Saturation Flow

Chapter 1: INTRODUCTION

1.1 Background

It is common knowledge to the people of Kathmandu Valley that its road traffic is suffering from congestion the main reasons being rapid population increase, haphazard urban sprawl, and inadequate urban infrastructures and planning (JICA, 2000). The congestion of roads and public transport are taking place even in the off-peak hours. Especially, the intersections and nearby areas are getting serious hits due to congestion affecting the day-to-day activities of the citizens. The problems seen at such intersections are severe traffic congestion, increasing traffic crashes, a substantial amount of vehicle emissions, degradation of urban amenities, etc.

Traffic congestion is a condition where the demand exceeds the capacity of the transport infrastructure which is characterized by slow traffic speeds, longer travel times, and long vehicle queues. When the use of a road and/or an intersection by vehicles increases to the extent of surpassing its capacity, the speed of the traffic stream slows and results in congestion. The problem of traffic congestion is even worse for developing countries like Nepal due to restricted rights of way, limited financial resources, and lack of advanced technology.

An intersection is where two or more roads either join or cross. The operating efficiency of a highway and the safety thereof depend on the number and types of intersections en-route and the efficiency of the design of these intersections (Khanna, Justo, & Veeraragavan, 2018). Intersections play an important role in managing conflicts and merging traffic streams. The geometric and traffic studies and assessments can be done at a selected intersection which leads to determining if the intersection is operating well in its capacity or if traffic flow exceeds the capacity. Travel time and delay analysis is a major part of the intersection study. Delay happening at the intersection is a major problem in the analysis of traffic congestion. The intersection delay study is valuable in evaluating the operating efficiency of a traffic intersection.

1.2 Problem Statement

The total number of motor vehicles plying across the country reached nearly 3.1 million as of mid-May, according to a data of Department of Transport Management (Poudel, 2018) (DoTM). The escalating number of vehicles in the Kathmandu valley, driven by the improvement of the economy and living standard of the population, has necessitated the need for wider road networks with advanced traffic control systems. However, the increasing population and haphazard urban sprawl have imposed limitations on land acquisition for road widening. Urban road networks have relatively big and closely spaced intersections. As a result, there is more traffic congestion, especially during peak hours. Kathmandu lacks even a single flyover, and not all the traffic lights, important tool to assist control of traffic, are in operating state. The majority of the busy crossroads have traffic police directing the traffic. Officials say that if all the traffic lights are in good condition, the traffic jam in the valley will be reduced by more than 40 percent (Singh, 2022). This has necessitated the implementation of efficient, state-of-the-art traffic management systems to mitigate congestion. One such intersection is Thapathali, which is equipped with channelizing islands and staged pedestrian crossings, however, during peak hours, traffic congestion is observed to extend beyond nearby intersections such as Maitighar, Tripureshwor and Kupondole. The Thapathali intersection experiences a significant volume of vehicular traffic due to the presence of government offices beyond the Maitighar intersection, also due to linkage between Kathmandu and Lalitpur via Bagmati Bridge to the south, as well as the proximity of two major hospitals (Norvic and Maternity Hospital) to the east of the intersection. Additionally, the presence of a large commercial shopping center (Bhatbhateni Supermarket) beyond the Tripureshwor intersection and proximity to the Kalimati Market also contribute to the high volume of trip generation at this intersection. Thus, an in-depth performance evaluation and improvement study must be conducted at the Thapathali intersection to improve the traffic flow.

1.3 Objective of Study

The primary objective of this study is to provide a current status of traffic in a signalized intersection of Thapathali in terms of degree of saturation (DoS), level of service (LoS), delay, queue length, and average travel speed and then provide multiple probable solution measures to improve the current situation.

The objectives are listed as:

1) To identify the current traffic situation and LoS at the intersection by evaluating level of service and delays after the calibration and validation of the simulation model.
2) To provide optimal solution to improve the existing condition of the intersection by making a comparative analysis among the alternatives based on travel time, delay & queue length.

1.4 Scope of Study

As per the objectives of the study following are the scopes that have been planned:

1) Make use of SIDRA Intersections (a computer-based advanced lane-based micro-analytical tool) for simulating present traffic under the existing geometric feature of the intersection.
2) To calibrate and validate the simulation model using peak hour traffic volume obtained from the video-graphic survey of the intersection.
3) Obtain the delays and travel times from the calibrated model.
4) Suggest alternative measures to improve the operating efficiency & LoS of the intersection.
5) Comparison and Analysis of delays, queue lengths, and travel speeds of the alternatives to determine the efficient solution.

1.5 Limitation of Study

The study was carried out under the following limitations:

1) The study does not consider neighboring intersections (Maitighar and Tripureshwor) and carries out analysis on an isolated study area.
2) Parallel analysis making use of other analysis software such as VISSIM, SimTraffic, CORSIM, etc. to obtain comparative study is overlooked.

1.6 Organization of Report

The report consists of the following five chapters:

Chapter 1: “Introduction” discusses briefly the condition of intersections in Nepal.

Chapter 2: “Literature Review” discusses the available literature in the field of traffic analysis of intersections and making use of Sidra.

Chapter 3: “Methodology” describes the steps followed for carrying out the study of traffic analysis.

Chapter 4: “Analysis and Design” explain the analysis stage of the study where models are interpreted and results are obtained.

Chapter 5: “Conclusion and Recommendations” highlights the conclusions drawn from the analysis and results from previous chapters and proposes a few recommendations based on the study.

Chapter 2: LITERATURE REVIEW

2.1 Traffic Signal Optimization

Signal optimization for the isolated intersection mainly focuses on optimizing cycle length, green signal ratio, and phase sequence, but pays less attention to phase design when traffic states vary over time. The unreasonable phase design lowers the effectiveness of the subsequent signal timing optimization. Furthermore, signal control of an isolated intersection lays a solid foundation for coordinated signal control for arterial intersections. Therefore, it is crucial to optimize the phase design of an isolated intersection (Liu & Wu, 2021).

In general, it was found that optimizing cycle lengths is more beneficial than optimizing splits. It can decrease the total amount of delay and the total travel time and increase the average speed. It may also decrease fuel consumption but may increase the amount of hydrocarbon and carbon monoxide emissions (Siddiqui, 2015).

The inefficient operation of traffic signals is a common problem certainly experienced by all network users. Improper or unjustified traffic control signals can result in excessive delay, excessive disobedience, increased use of less adequate routes, and significant increases in the frequency of rear-end collisions (US Department of Transportation, 2009).

A properly designed and timed traffic signal can be expected to provide for the orderly and efficient movement of people. Besides this, traffic signals can maximize the volume of movements served at the intersection hence increasing the capacity. They are also expected to reduce the frequency and severity of certain types of crashes and to provide appropriate levels of accessibility for pedestrians and side street traffic (Koonce & Rodegerdts, 2008).

Traffic signal retiming is one of the most cost-effective ways to improve traffic flow and is one of the most basic strategies to help mitigate congestion. The benefits of up-to-date signal timing include shorter commute times, improved air quality, reduction in certain types and severity of crashes, and reduced driver frustration (Federal Highway Administration, 2007).

2.2 Performance Evaluation

Synchro and SimTraffic models were created in assessing and optimizing signal timing plans for a signalized intersection with separate models for the afternoon and off-peak periods. After optimizing the existing signal timing plan, using Synchro's "Optimization by Intersection Splits", it was found that the intersection average delay decreases in the orders of 9 to 11% for the off-peak and 4 to 5% for the PM-peak. Using Synchro's "Optimization by Cycle Length", it was found that the delays decrease in the orders by 30 to 35% both for the off-peak and the PM-peak hours (Siddiqui, 2015).

Abojaradeh et al. conducted a comprehensive traffic analysis at a signalized intersection utilizing HCM (Highway Capacity Manual) and HCS (Highway Capacity System) computer systems. The results indicated a delay of 473 sec/veh with a Level of Service (LoS) rating of F. In response to these findings, the researchers proposed four distinct alternatives. Notably, the fourth alternative, involving the construction of two overpasses, demonstrated significant efficacy by reducing the Level of Service to LoS-C, accompanied by a diminished delay of 27 sec/veh. (Abojaradeh, Msallam, & Jrew, 2014).

Kumar and Dhinakaran determined control delay for five isolated signalized intersections using guidelines by HCM 2000 and didn't find a good correlation between observed and predicted delay. So, they accounted field measured control delay for defining LoS (Prasanna & Dhinakaran, 2013).

Shrestha and Marsani evaluated New Baneshwor Intersection using VISSIM and proposed five alternatives and found the 5th alternative i.e. Three-phase signal planning with a flyover by providing U-Turn at 300 m to be the most effective which reduced LoS from F to C. One of the alternative solutions for the congestion that occurs at the intersection of New-Baneshwor is to apply the efficiency of the intersection that is not provided with the Four phases of signal planning, Three phases of signal planning by providing U-Turn, Fly over with existing scenario, Four phases signal planning with a flyover, Three phases signal planning with a flyover by providing U-Turn verifying queue pocket area for U-Turn. Based on the travel time and delay reduction with 5 comparative modellings it shows that the three phases of signal planning with a flyover by providing a U-Turn effectively decrease delay and travel time by 81.92% and 80.1% in morning and evening peak time respectively maintaining a LoS C, in addition, Maitighar, Tinkune, Old Baneshwor, as well as Sankhamul lane, is found to have decreased by minimum 60% in the morning and evening which was found to be the most technically efficient to be applied. (Shrestha & Marsani, 2017).

2.3 SIDRA Intersections

The SIDRA Intersection software is an advanced lane-based micro-analytical tool for design and evaluation of individual intersections and networks of intersections including modelling of separate Movement Classes (Light Vehicles, Heavy Vehicles, Buses, Bicycles, Large Trucks, Light Rail/Trams and so on). It provides estimates of capacity, level of service and a wide range of performance measures including delay, queue length and stops for vehicles and pedestrians, as well as fuel consumption, pollutant emissions and operating costs (Akcelik & Associates Pty Ltd, 2018).

The SIDRA Intersection software is an advanced micro-analytical traffic analysis tool developed by the Australian Road Research Board (ARRB). SIDRA is a very powerful analytical program for signalized intersections (Taale & Zuylen, 2001). The flexibility of the SIDRA Intersection permits its application in many other situations, including uninterrupted traffic flow conditions and merging analysis (Akcelik & Besley, Operating cost, fuel consumption, and emission models in aaSIDRA and aaMOTION, 2003). The use of the HCM version of the SIDRA Intersection is based on the calibration of model parameters against the highway capacity manual (Riley, 2000).

Darma et. al. used SIDRA and Transyt-7F software to determine the delay of signalized intersections based on HCM methods and found that cycle time, inter-green time, number of phasing, number of the lane, and LTOR (Left turn on red) have a significant correlation (Darma, Karim, Mohamad, & Abdullah, 2005).

The key outcome of the model comparison was that SIDRA tended to calculate higher average delay statistics than VISSIM for intersections with low traffic demand and where some geometric negotiation is required. Further investigation identified that SIDRA automatically includes a geometric delay component within its calculation of average vehicle delay. By contrast, the equivalent statistic calculated by VISSIM ignores geometric delay (when coded using reduced speed areas) and incorporates only genuine control delay. This identifies a key difference between the methods used by each package to report a performance measure that is commonly assessed in TIAs (Fichera, 2012).

Irtema et al. found that the morning period is better than the evening period for the value of delay, queue, journey time, and speed that was obtained from practical measuring in the study area (Irtemih, Ismail, Ali, & Ladin, 2015).

Ali et. al. found that SIDRA Intersection software was able to give an estimate of the current situation of traffic flow in Nicosia city of Cyprus. The results showed that the level of service was low, resulting in low speeds, and lots of delays during the evening and morning peak hours (Ali, Reşatoğlua, & Tozan, 2018).

Mohammed et. al. used SIDRA to assess the performance of the Jordan intersection and demonstrated that the LoS is D with an average delay of 35 sec/veh and a degree of saturation of 0.996 v/c (Mohammed, Jony, Shakir, & Ambak, 2018).

Shrestha and Dhungel used SIDRA Intersection 5.1 to investigate the operational performance of the Old Baneshwor Intersection year 2018 and explored various improvements for the current year up to 2028. The overall performance level of the intersection at the present condition with traffic police control without any improvement was found to be at LoS F, oversaturated with DoS = 1.16, average overall intersection delay of 98.3 sec/veh. Among the 6 options, the 6th option is the best performing as it had the least PI = 116.5 and the least delay of 32.6/veh. Also, the same option with a minor geometric upgrade will be sufficient till the year 2028 (Shrestha & Dhungel, 2018).

Aslan et al. investigated the impact of signal coordination on delay time employing SIDRA and VISSIM. The study revealed that implementing coordination between the first and second intersections of Marmul Street, prior to the enhanced geometric design, resulted in a notable reduction of up to 3.36 percent in the total vehicle delays for the system. (Aslan & Ahadi, 2019).

The study of Dhakal et al. delivered a comprehensive overview of signalized intersections in Satdobato, situated within the central business district of Lalitpur, serving as a pivotal link for bustling approaches grappling with congestion. The microsimulation software 'SIDRA Intersection 8.0' was employed to model environmental and traffic flow parameters, with meticulous calibration and validation against field data. Intersection performance was assessed based on critical metrics such as LoS, delay, and back of the queue. Following the evaluation, the study implemented performance enhancement strategies, including the optimization of signal timing by adjusting cycle lengths and splitting timing. Furthermore, the management of continuous left-turning movements within signal time frames was addressed. The study concluded by offering recommendations rooted in a comprehensive evaluation of system performance post-implementation, aiming to elevate the overall efficiency of the intersection (Dhakal, Tiwari, & Luitel, 2023).

The study of Tiwari et al. aimed to enhance traffic flow at two busy intersections, namely Kanti Children's Hospital and Shital Niwas, situated in Kathmandu Valley, Nepal. The research focused on evaluating the existing traffic conditions and mitigating delays and queues through the exploration of various alternatives, including signal coordination. A comprehensive survey was conducted to gather morning peak hour traffic volume data and geometrical features of the intersections. Subsequently, a signalized intersection model was developed in SIDRA software. The model underwent meticulous validation based on observed and modeled queue lengths for each approach, facilitating an evaluation of the intersections' existing performance. Several alternatives were then devised to optimize intersection performance. The outcomes demonstrated that coordinating the signal systems led to a substantial reduction in average delay time and maximum queue length at both intersections. Specifically, at the Shital Niwas intersection, the average delay time decreased from 106 seconds per vehicle to 26.5 seconds per vehicle, while at the Kanti Children's Hospital intersection, it decreased from 43.1 seconds per vehicle to 21.7 seconds per vehicle. Similarly, the maximum queue length saw a significant reduction, dropping from 744.7 meters to 122 meters at Shital Niwas and from 456.2 meters to 147.7 meters at Kanti Children's Hospital (Tiwari, Luitel, & Pokhrel, 2023).

Chapter 3: METHODOLOGY

3.1 Research Design

A research design is a plan, structure, and strategy of investigation so conceived as to obtain answers to research questions or problems. The plan is the complete scheme or program of the research study. The research design for this study is shown in **Figure 3-1**. As traffic congestion is evident in the intersections of Kathmandu valley, a problem of congestion mitigation at intersections was identified. Based on the question “How to mitigate congestion and improve travel time and reduce delay at intersections?” numerous kinds of literature were studied and reviewed which led to narrowing objectives after a proper methodology was identified. Based on previous studies and surveys conducted by JICA (JICA, 2019), it is can be considered as one of the major intersections of the Kathmandu valley. As the Thapathali intersection connects two major hospitals (Norvic Hospital and Maternity Hospital), Kupondole bridge leading to Lalitpur district, Bhatbhateni Super Market at Tripureshwor, it was selected as the study area. Based on works of literature, it was decided that video graphic surveys will be an easy and effective means to collect traffic flow data and SIDRA software will be used as traffic analysis and modelling software. Based on the analysis of results from SIDRA, sensible conclusions will be drawn and recommendations will be provided.

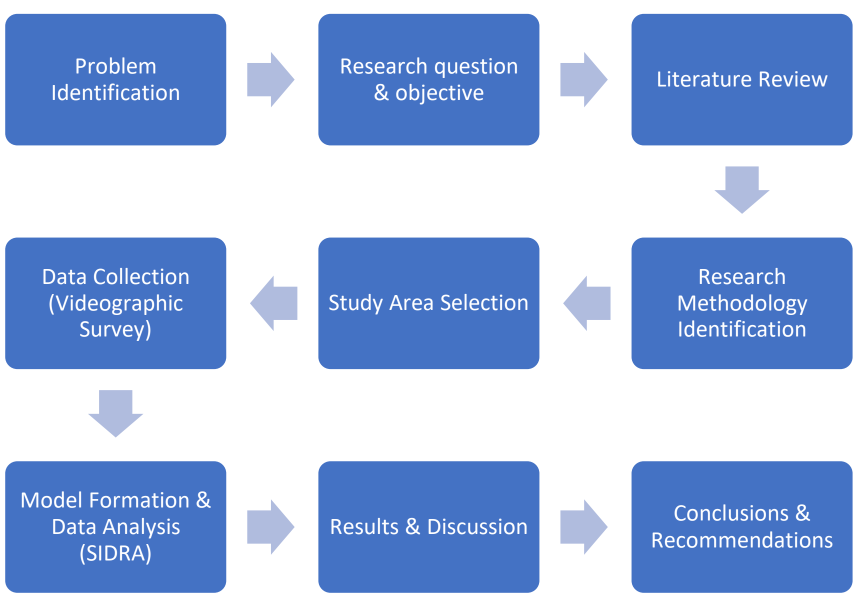


Figure 3-1: Framework of Research Design

3.2 Study Area

For this research study, the study area selected is the Thapathali Intersection at the position of 27.690678º N, 85.317625º E. The two main roads Prashuti Griha Marg – Tripura Marg and Thapathali Road – Kupondole Road cross at this intersection. It is a 4-legged intersection with non-operating traffic signals rather managed by traffic police. The south leg is towards Kupondole (Kupondole Leg), the east leg toward Maternity Hospital Road (Maternity Road Leg), the north leg is towards Maitighar (Maitighar Leg), and the west leg towards Tripureshwor (Tripureshwor Leg).

Figure 3-2: Drone Image of Thapathali Intersection

Source: Aviyaan Consulting (P) Ltd.

3.3 Data Collection

For the analysis of the intersection data categories such as geometric characteristics, traffic characteristics, and signal control characteristics are required. Most of the data associated with these characteristics are collection as primary data from videographic surveys and field observations.

The following data were collected:

- Intersection geometry which includes lane usage and link distances
- Existing Intersection Turing Movement Counts
- Classified count of vehicles
- Peak period and Off-peak period observations
- Current signal timing and phasing data
- Cruise Speeds data
- Back of Queue data

Other data such as approach leg distances were obtained from the measure tool available in QGIS, passenger car units (PCUs), basic saturation flow, vehicle class growth rates, vehicle dimensions, queue space & vehicle occupancy were adopted as secondary data.

An Ezviz video camera, as shown in **Figure 3-4**, was used as field data collection tool for recording the video of traffic flow at the Thapathali intersection for 5 Days from 01/06/2022 to 05/06/2022 which included three weekdays and two weekends.

Figure 3-3: Installation of Video Camera

Figure 3-4: Camera capturing Traffic flow

The camera was firmly attached to a column on the terrace with the help of metal wire and tape as shown in **Figure 3-3**. The camera was powered with a normal 5V battery which was continuously in charging mode via the electricity supply of the building. The whole power supply component was wrapped in a plastic bag to shield it from rain. The videos of traffic flow were obtained in chunks of 256 MB data files which had to be merged to obtain workable video files. The video chunks of Day-1 were merged in a manner so that one whole day video of 16 hours (6 am to 10 pm) is divided into 4 parts each of 4-hour duration. So, Part 1 (6 am to 10 am), Part 2 (10 am to 2 pm), Part 3 (2 pm to 6 pm), and Part 4 (6 pm to 10 pm) were obtained. Similar steps were followed for the remaining 4 days of the traffic flow video. Therefore, in totality for 5 days, 20 video files for each of 4 hours of traffic flow were acquired for the traffic counting purpose. For this purpose of video editing and merging, the software "LM Video Editor" was developed which is shown in **Figure 3-5**.

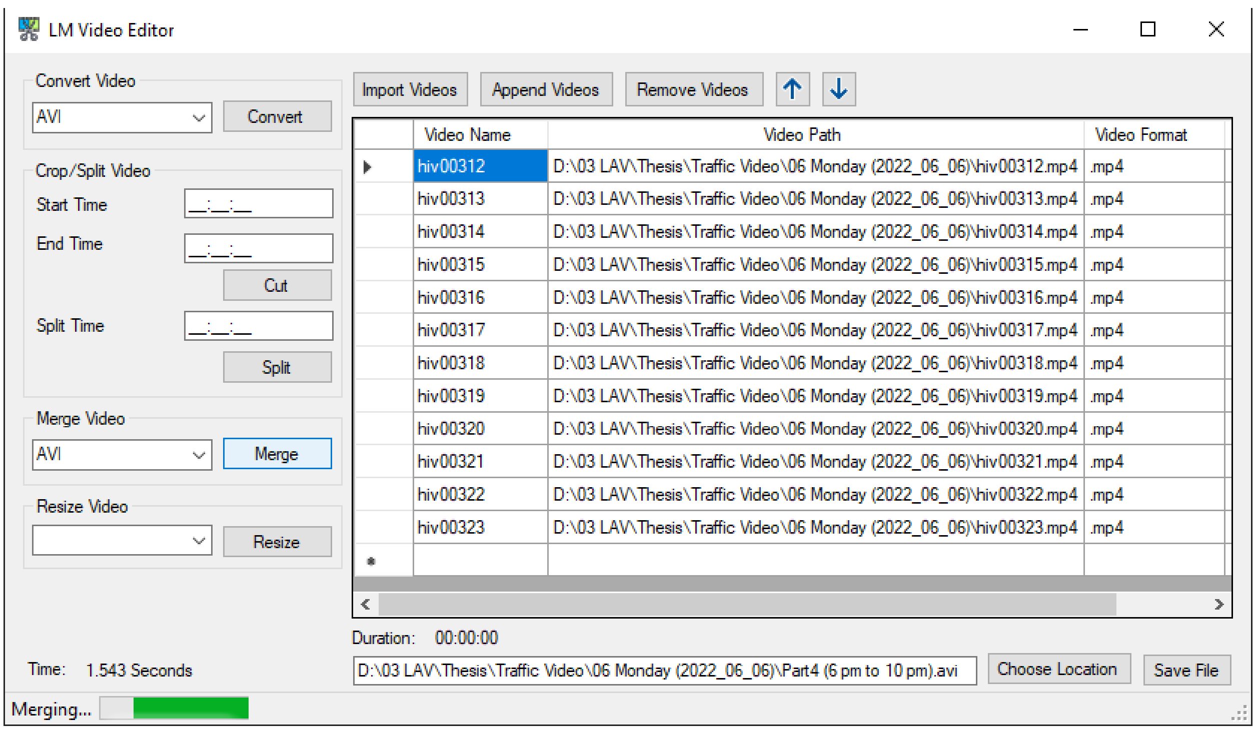


Figure 3-5: Video editing software to merge video chunks.

The classified vehicle count of the traffic flow was carried out manually using a self-developed traffic counting software as shown in **Figure 3-6**. In total, 17 classes of vehicle and 1 pedestrian movement are supported by the traffic counting software. Specific keystrokes are assigned for each class of movement. For example, a numeric keystroke of "0" is assigned for motorbikes and “1” is assigned for cars. This traffic counting software then produces a result in CSV format with details of each movement along with the time. The CSV result of the traffic count for all 4 parts of the traffic flow video was merged into a single CSV file containing data of 16 hours of traffic flow from 6 am to 10 pm using the same software. Further, the same software was used to segregate the result to produce a report in terms of traffic volume in 15 minutes intervals in xlsx format. A sample of the result and report are shown in **Figure 3-7** and **Figure 3-8** respectively.

Figure 3-6: Manual Traffic Counting Software

	A	B	C	D	E	F	G
1	Station	Directon	VideoFileName	StartDate	StartTime	VecType	Time
2	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Standard Bus	7:43:28
3	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Standard Bus	7:02:35
4	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Standard Bus	6:42:23
5	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Mini Bus	6:47:14
6	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Car	10:00:22
7	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Car	9:59:51
8	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Car	9:58:23
9	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Car	9:56:57
10	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Car	9:56:10
11	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Car	9:53:06
12	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Car	9:53:01
13	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Car	9:52:36
14	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Car	9:52:13
15	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Car	9:44:46
16	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Car	9:44:22
17	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Car	9:43:46
18	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Car	9:42:15
19	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Car	9:42:02
20	Thapthali	Maitighar_L	Part1	6/5/2022	6:00:59	Car	9:40:42

Figure 3-7: Sample of Traffic count in CSV Format

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1		6/2/2022																	
2		Start Time	End Time	Mutli Axle Truck	Heavy Truck	Light Truck	Standard Bus	Mini Bus	Micro Bus	Car / Taxi	Motor Cycle	Utility Vehicle	Tractor	Motorised Three Wheeler	Four Wheel Drive	Power Tiller	Rickshaws	Bullock Cart / Tanga	Total
3		5:00:00	6:00:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4		6:00:00	7:00:00	0	0	1	1	0	0	17	74	2	0	0	0	0	0	0	95
5		7:00:00	8:00:00	0	0	0	1	0	0	16	75	1	0	0	4	0	0	0	97
6		8:00:00	9:00:00	0	0	0	0	0	0	34	85	3	0	0	7	0	0	0	129
7		9:00:00	10:00:00	0	0	0	0	0	0	49	139	2	0	0	7	0	0	0	197
8		10:00:00	11:00:00	0	0	0	0	0	0	65	210	3	0	1	15	0	0	0	294
9		11:00:00	12:00:00	0	0	0	0	0	0	64	215	6	0	0	14	0	0	0	299
10		12:00:00	13:00:00	0	0	0	1	0	0	75	179	6	0	0	13	0	0	0	274
11		13:00:00	14:00:00	0	0	0	1	0	1	74	204	4	0	0	14	0	0	0	298
12		14:00:00	15:00:00	0	0	0	0	0	0	77	173	6	0	0	19	0	0	0	275
13		15:00:00	16:00:00	0	0	0	0	0	0	66	152	1	0	0	10	0	0	0	229
14		16:00:00	17:00:00	0	0	0	0	0	0	79	179	3	0	0	15	0	0	0	276
15		17:00:00	18:00:00	0	0	0	2	0	0	68	278	1	0	0	16	0	0	0	365
16		18:00:00	19:00:00	0	0	0	0	0	0	56	293	4	0	0	14	0	0	0	367
17		19:00:00	20:00:00	0	0	0	0	0	1	25	125	3	0	0	10	1	0	0	165
18		20:00:00	21:00:00	0	0	2	1	0	1	20	41	2	0	0	3	0	0	0	70
19		21:00:00	22:00:00	0	3	0	0	0	0	10	29	2	0	0	0	0	0	0	44
20		22:00:00	23:00:00	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2

Figure 3-8: Sample of Traffic count report in xlsx format

3.4 Intersection Modelling

For the analysis of raw data obtained from traffic flow video and other field observations and other secondary sources; a computer-based micro-analytical software called SIDRA Intersection was employed. A wide range of data was required to be fed into the software such as Intersection data, movement definitions (user-defined in addition to Light and Heavy Vehicle movements), lane geometry, lane movements, traffic volumes, and existing phasing and timing data. With these data, a model of the Thapathali intersection was created in SIDRA.

3.4.1 Intersection and Approach Data

The intersection configuration was established by setting 4 approach legs in the South, East, North, and West directions. The south leg was named “Kupondole” with an approach distance of 530.0 m, the east leg was named “Maternity Road” with an approach distance of 320.0 m, the north leg was named “Maitighar” with an approach distance of 520.0 m, and the west leg was named “Tripureshwor” with an approach distance of 500.0 m. The leg geometry is the main intersection configuration parameter (Akcelik & Associates Pty Ltd, 2018). All the legs were a leg geometry of type “Two Way”.

3.4.2 Movement Definition

The movement definition in SIDRA includes movement class and origin-destination movement.

3.4.2.1 Movement Class

SIDRA uses a system to aggregate vehicle groups into movement groups. SIDRA by default includes two standard vehicle classes viz., Light Vehicles (LV) and Heavy Vehicles (HV). In addition to default vehicle classes, another standard vehicle class i.e., Buses (B) was also added to the analysis. Furthermore, six user-defined vehicle classes were added. They are Mini Buses (mB), Micro Buses (uB), Cars (C), Jeeps (J), Tempos (T), and Motor Cycles (MC). The Light Vehicle and Heavy Vehicles classes were treated as Light trucks and Heavy trucks respectively. The Kathmandu Valley Intelligent Traffic System Project (KVITSP) (Department of Road, 2022) was referred for PCU factors as shown in **Table 3-1**.

Table 3-1: Adopted PCU Factors

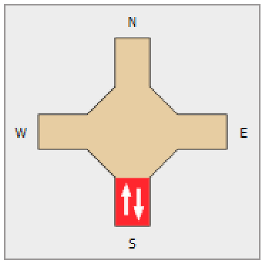
SN	Vehicle Class	Adopted PCU Factor
1	Light Vehicles (LV)	1.5
2	Heavy Vehicles (HV)	3.0
3	Buses (B)	3.0
4	Mini Buses (mB)	2.5
5	Micro Buses (uB)	1.5
6	Cars (C)	1.0
7	Jeeps (J)	1.0
8	Tempos (T)	0.75
9	Motor Cycles (MC)	0.25

3.4.2.2 Origin-Destination Movement

The Origin-Destination (OD) Movement is characterized as the traffic flow distinguished by its origin (approach) and destination (exit) at an intersection, as defined in the SIDRA Glossary of Road Traffic Analysis Terms by Akcelik (2017). Consequently, it is imperative to allocate OD movement to all approach legs, as evident in the intersection's observational data. All the approach legs had three traffic movements viz., Left turn, Through & Right Turn except for the Maternity Road approach leg as through and right turn movements were restricted in the field as shown in **Figure 3-9**.

Table 3-2: Origin-Destination Movements for Approach Legs

Approach Selector

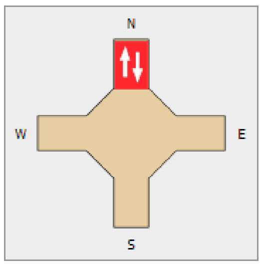


Kupondole

Origin - Destination Movements

From South to Exit:	W	N	E	S
	L2	T1	R2	U
Movement Exists	☑	☑	☑	☐
OD Movement ID	1	2	3	

Approach Selector

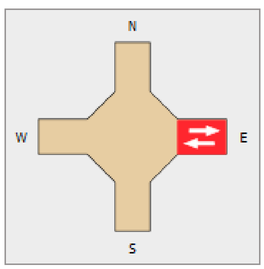


Maitighar

Origin - Destination Movements

From North to Exit:	E	S	W	N
	L2	T1	R2	U
Movement Exists	☑	☑	☑	☐
OD Movement ID	7	8	9	

Approach Selector

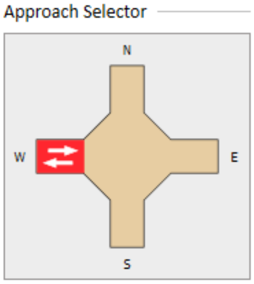


Maternity Road

Origin - Destination Movements

From East to Exit:	S	W	N	E
	L2	T1	R2	U
Movement Exists	☑	☐	☐	☐
OD Movement ID	4			

Approach Selector



Tripureshwor

Origin - Destination Movements

From West to Exit:	N	E	S	W
	L2	T1	R2	U
Movement Exists	☑	☑	☑	☐
OD Movement ID	10	11	12	

Figure 3-9: Traffic sign boards on Maternity Road Leg

3.4.3 Lane Details

The lane details include details regarding lane configuration, lane discipline, and lane data. The parameters like the number of approach lanes, exit lanes, lane type, lane control, lane geometry, lane length, lane width, vehicular movement associated with the lane, lane basic saturation flow, etc. are described under lane details.

3.4.3.1 Lane Configuration

The lane configuration data includes the number of approach and exit lanes and their type (normal, short, or bypass). The type of traffic control adopted for each lane is also included in the lane configuration. The traffic control can either be "Continuous" if the lane is not controlled or "Signal" if the lane is controlled either by signal or traffic police. The geometric properties such as lane length, lane width, and grade were extracted from the field as well as from the drone image of the intersection. The geometric properties such as lane length, lane width, and grade were extracted from the field as well as from the drone image of the intersection.

3.4.3.2 Lane Discipline

All the OD movements that exist for the selected approach are selected to indicate that the selected OD movement is allocated to the selected lane.

3.4.3.3 Lane Data

The fundamental saturation flow rate represents the maximum flow rate attainable under optimal conditions at signalized intersections, unaffected by factors that might diminish the consistent discharge rate of queued vehicles during the green signal phase (Akcelik, SIDRA Glossary of Road Traffic Analysis Terms, 2017). SIDRA uses basic saturation flow values in through car units per hour (tcu/h) The basic saturation flow was allocated to each lane of each leg as per Indo-HCM (CSIR, 2017) formula shown below.

$USF_o = 630$; for $w < 7.0$m

$USF_o = 1140 - 60w$; for $7.0 <= w <= 10.5$m

$USF_o = 500$; for $w > 10.5$m

Where,

USF_o = unit base saturation flow rate (in PCU/hour/m).

w = effective width of approach in meters (m).

The saturation speed denotes the constant departure speed of vehicles exiting the queue during the green signal phase at traffic intersections, measured specifically at the stop line (Akcelik & Associates Pty Ltd, 2018). The saturation speed is subject to various constraints related to the approach cruise speed and the negotiation speed. SIDRA calculates the saturation speed for through movements as 0.75 times the approach cruise speed i.e., $v_s = 0.75\ v_{ac}$ where as for the turning movements it is taken as the exit negotiation speed i.e., $v_s = v_{en}$.

3.4.4 Volume Data

The unit time for volumes and peak flow period was taken as 60 minutes and 15 minutes respectively for the intersection. The traffic volume is the number of vehicles (arriving or departing) at a given point on a lane or carriageway during a specified period of time (Akcelik, SIDRA Glossary of Road Traffic Analysis Terms, 2017). The classified vehicle count obtained in 15 min intervals from traffic video as explained in the data collection step is used to enter the peak hour volume. The vehicle volumes during the peak hour for each approach leg for each vehicle class were input separately. The vehicle volume data for all 5 days are shown in Appendix A. A PHF higher than 0.95 may be used in urban areas if justified by traffic conditions (Florida Department of Transportation, 2021). Thus, a PHF of 0.95 is taken for all the approach legs. The Flow Scale factor is taken as default values provided by SIDRA.

3.4.5 Vehicle Movement Calibration

The speed data, vehicular movement data, and timing data were extracted from various primary and secondary sources and fed to the SIDRA software for model calibration.

3.4.5.1 Cruise Speed & Negotiation Speed

According to the SIDRA Glossary of Road Traffic Analysis Terms, cruise speed is characterized as the continuous travel speed—specifically, the midblock speed of a vehicle on the approach or exit side of an intersection, unimpacted by intersection-related delays. This speed is estimated by adjusting the speed limit for factors such as side friction, road geometry, and traffic volume. It is noteworthy that, in the absence of speed limit signs, the speed limit itself could serve as the cruise speed. But, in the absence of speed limit signs, a speed survey was carried out for each approach leg during off-peak hours to determine the cruise speed. For this purpose, Manual Short-Base Method for speed survey as described in ORN-11 published by (Overseas Centre Transport Research Laboratory).

The short-base method of speed survey involves creating a specific length of the road, over which vehicles can be timed. The length of this road is determined by the speeds of the vehicles on that road, with longer lengths needed for higher speeds. The ends of the short-base length of 30 m were marked on the road surface with paint across the road edge of the approach legs. The short-base length was measured accurately using a metal tape-measure. Additionally, a sampling line was marked upstream of the start line, so that the sample vehicle could be selected before recording its travel time. The duration taken by the sampled vehicle to travel from the starting point upstream to the terminating point downstream was accurately measured using a stopwatch on a mobile phone. This information was meticulously recorded, inclusive of the corresponding vehicle class designation. The cruise speed data is shown in Appendix B. The 85th percentile was taken as the cruise speed for the approach leg as it is commonly used to describe speeds that exclude extremely fast drivers (and gross measuring errors) and gives an estimate of what the majority of drivers consider a top limit. Both approach and exit cruise speeds were assumed to be the same for each approach leg (i.e., $v_{ac} = v_{ec}$).

Negotiation Speed is the vehicle speed during travel in the intersection negotiation area. In SIDRA, approach and exit negotiation speeds are equal (i.e., $v_{an} = v_{en}$). For through movements, the approach negotiation speed is set as the approach cruise speed (i.e., $v_{an} = v_{en} = v_{ac}$).

3.4.5.2 Queue Space, Vehicle Dimensions, and Occupancy

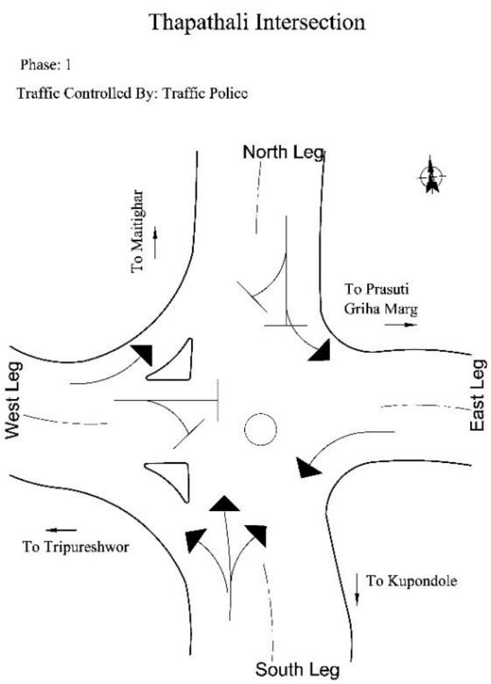
Queue Space is defined as the distance between the front ends of two successive queued vehicles in the same traffic lane. Vehicle length is the average vehicle length for a movement class. Vehicle occupancy refers to the average number of individuals per vehicle, inclusive of the driver. This metric can be specified for each Origin-Destination (OD) movement and movement class (Akcelik, SIDRA Glossary of Road Traffic Analysis Terms, 2017). There are a variety of vehicle sizes that can influence traffic characteristics, due to their diverse sizes and operational capabilities. The Thapathali intersection experiences a heterogeneous mix of vehicle types, which can affect the traffic flow. The values for queue space and vehicle occupancy adopted for each vehicle class in the traffic model are adopted from the Kathmandu Valley Intelligent Traffic System Project (KVITSP) (Department of Road, 2022).

3.4.6 Phasing & Timings

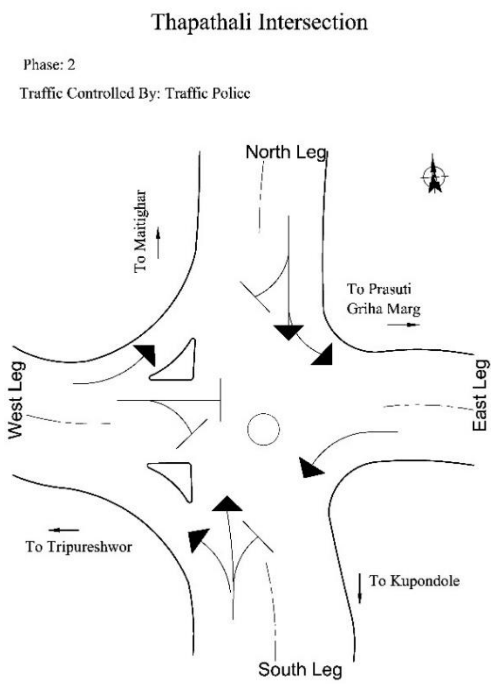
Phase is that part of a signal cycle during which one or more movements receive the right of way subject to the resolution of any vehicle or pedestrian conflicts by priority rule. A phase is identified by at least one movement gaining the right of way at the start of it and at least one movement losing the right of way at the end of it. Phase frequency is defined as the proportion of signal cycles during an analysis (flow) period in which the signal phase is activated.

The intersection is continuously controlled by traffic police as a result the cycle and phase timing as assigned by the traffic police were observed for the particular hour considered from the recorded video of the intersection. The following 5 phases with fixed time signal analysis method were input for the SIDRA model which are as shown in **Table 3-3** below:

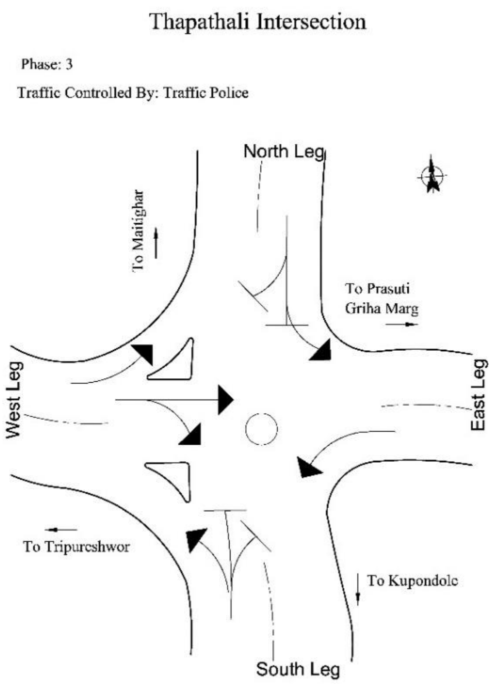
Table 3-3: Phase schematic diagram



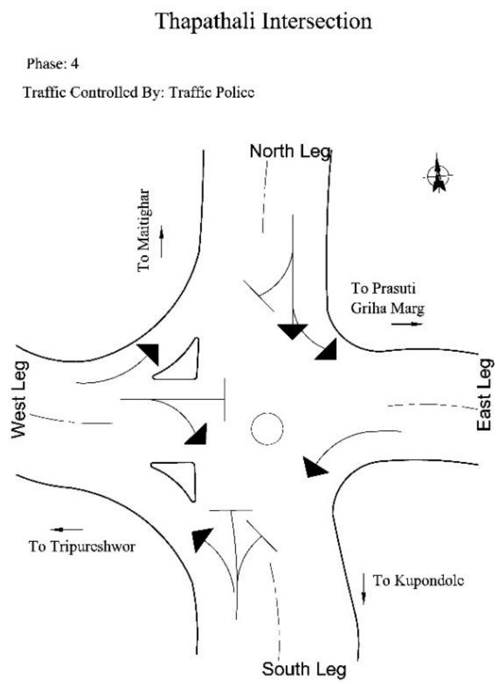
Schematic Diagram for Phase 1



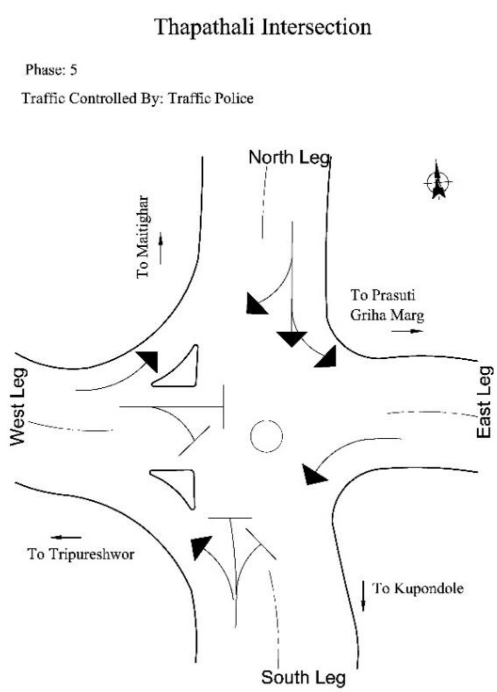
Schematic Diagram for Phase 2



Schematic Diagram for Phase 3



Schematic Diagram for Phase 4



Schematic Diagram for Phase 5

3.5 Calibration and Validation of the Model

Model calibration and validation are the most important, yet challenging steps of developing a realistic microsimulation model.

- Calibration is an iterative process whereby the model parameters are adjusted until simulation MOEs reasonably match the field-measured MOEs. Calibration requires both software expertise and knowledge of existing traffic conditions.
- Model validation is the process of testing the performance of the calibrated model using an independent data set (not previously used in the calibration). Validation is an additional check to confirm that a model has been correctly calibrated and closely matches the existing conditions.

If the residual errors between simulated and field-measured MOEs are within an acceptable margin of error, the model is calibrated; otherwise, model parameters are modified until all MOEs' residual errors are within the acceptable range (Florida Department of Transportation, 2021).

After the formation of the intersection model using the various inputs such as approach data (distance, leg geometry), movement definitions (vehicle classes and their PCU, OD movements), lane detailing (number of approach and exit lanes, their configuration, type, length, width, discipline, basic saturation flow, and saturation speed), volume data, vehicle movement calibration data (cruise speeds, negotiation speed, dimensions, occupancy, start loss and end gain times), phase timings (phase duration and frequency), the next step is to calibrate the model so formed.

The default vehicle calibration parameters as produced by SIDRA are shown in **Table 3-4** .

Table 3-4: Default parameters of SIDRA

Parameters	Vehicle Classes								
	Light Trucks	Heavy Trucks	Buses	Mini Buses	Micro Buses	Cars	Jeeps	Tempos	Motor Cycles
PCU	1	1.65	1.65	1	1	1	1	1	0.5
Approach Cruise Speed (kmph)	60	60	60	60	60	60	60	60	60
Exit Cruise Speed (kmph)	60	60	60	60	60	60	60	60	60
Queue Space (m)	7	13	13	7	7	7	7	7	2
Vehicle Length (m)	4.5	10	10	4.5	4.5	4.5	4.5	4.5	1.8

Parameters		Vehicle Classes								
		Light Trucks	Heavy Trucks	Buses	Mini Buses	Micro Buses	Cars	Jeeps	Tempos	Motor Cycles
Vehicle Occupancy (persons/veh)		1.2	1.2	30	1.2	1.2	1.2	1.2	1.2	1
Turning Vehicle Factor	Left Turn	1.05	1.09	1.09	1.05	1.05	1.05	1.05	1.05	1.05
	Through	1	1	1	1	1	1	1	1	1
	Right Turn	1.05	1.09	1.09	1.05	1.05	1.05	1.05	1.05	1.05
Gap Acceptance Factor		1	1.5	1.5	1	1	1	1	1	1
Opposing Vehicle Factor		1	1.5	1.5	1	1	1	1	1	0.5
Start Loss (sec)		3	3	3	3	3	3	3	3	3
End Gain (sec)		3	3	3	3	3	3	3	3	3

Queue Space (Jam Spacing) is a key capacity and performance parameter for all intersection types and networks as it is used in estimating queue distance. SIDRA can estimate the back of the queue or the cycle-average queue for all types of intersection, and for each of these two types of queue length measures, the average value, as well as the 95th percentile values, are estimated. In the case of the queue length statics, it is important to match the statistics used in SIDRA to the statics observed in the field considering possible variation in the statistic that can be generated using SIDRA (Akcelik & Associates Pty Ltd, 2018).

As per Traffic Analysis Handbook by FDOT, the calibration target in terms of queue length in the traffic simulation model is to achieve the difference between simulated and observed queue lengths to be within 20% (Florida Department of Transportation, 2021). For this, a mobile application “SW Maps” was utilized where the last vehicle position in the queue was recorded as a feature. The data collection was carried out by mobilizing three personnel to each approach leg of the intersection during the peak hour period for five days. The project data obtained from the SW Maps application was exported in the Shapefile format and then imported into the open-source GIS software, QGIS. The individual queue points were then measured from the respective stop lines of the approach legs using QGIS and subsequently tabulated in a spreadsheet program, such as Microsoft Excel (as shown in Appendix D). The 95th percentile queue length was calculated using the formula provided in MS-Excel, which represents the observed queue lengths.

The field data of Day-1 and Day-2 was fed to SIDRA as input and a simulation run was performed to obtain the simulated queue length. A comparison between the observed and simulated queue lengths is made for the calibration of the model. To validate the simulation model, the vehicle volume and phase timing was modified to match the data from Day-3 while all other parameters were kept constant. The simulated queue length was then compared with the observed queue length for Day-3. The same procedure for calibration and validation of the simulation model was repeated for the weekend days (Day-4 and Day-5) where the model was calibrated using data from Day-4 and then validated using data from Day-5.

3.6 Evaluation of Operational Performance of the Intersection

Following the processing of the intersection model in SIDRA for peak hour traffic on both weekdays and weekends under current conditions, and the calibration and validation of the model, various performance statistics were extracted. Additionally, performance enhancement alternatives, such as options for lane reconfiguration, lane discipline reconfiguration, signal retiming, and phase reconfiguration were proposed. These options are discussed in sub-sections **4.12** and **4.13** of section **Chapter 4: DATA ANALYSIS**. The best option was selected by comparing the performance statistics among the alternatives. Using traffic volume projections, the chosen option was evaluated again for performance statistics under future traffic volume. Based on this analysis, several conclusions and recommendations are drawn and discussed in **Chapter 5: CONCLUSION AND RECOMMENDATION .**

The performance statistics, defined as per (Akcelik, SIDRA Glossary of Road Traffic Analysis Terms, 2017), that were extracted and analyzed are as follows:

3.6.1 Degree of Saturation (DoS)

The degree of saturation is the ration of arrival (demand) flow rate to capacity during a given flow period. It is also known as the volume-to-capacity ratio (v/c). It is a measure of the level of congestion. Depending upon the value range of degree of saturation, traffic flow in the intersection can be categorized into three categories viz. under saturated, maximum capacity, and over saturate condition. A v/c ratio of 1 means that the road or lane is operating at its maximum capacity. This means that the volume of traffic on the road or lane is equal to the maximum amount of traffic that it can handle without causing congestion or delay. When the v/c ratio is greater than 1, it means that the volume of traffic exceeds the capacity of the road or lane, leading to congestion and delay. Conversely, a v/c ratio of less than 1 indicates that the road or lane has unused capacity.

3.6.2 Delay

Delay is characterized as the additional travel time encountered by a vehicle in comparison to the base travel time, which represents the free-flow travel time. Average delay considering all vehicles that are queued and not queued is a common performance measure used for intersection analysis. The average delay can be used to evaluate the efficiency and effectiveness of the intersection and inform decision-making for improvement. The calculation of average intersection delay takes into account various factors such as traffic volume, signal timing, geometric design, and road network conditions. SIDRA incorporates geometric delay in the calculation of average delay value during the analysis of the Intersection.

3.6.3 Level of Service (LoS)

The Level of Service (LoS) serves as a metric evaluating the operational efficiency of traffic on specific segments, including roadways, traffic lanes, approaches, or intersections. It relies on various measures like delay, degree of saturation, density, speed, congestion coefficient, speed efficiency, or travel time index over a defined flow period. This method provides a quantifiable categorization of performance, denoting the Level of Service on a scale from A to F. In this scale, LoS A indicates optimal operating conditions, while LoS F indicates the least favorable operating conditions. SIDRA uses the average delay to determine the LoS as specified by HCM. In this analysis study, Delay and v/c (HCM 2010) method opted for LoS calculation.

3.6.4 95th Percentile Back of Queue (BoQ)

The Back of Queue (BoQ) is defined as the farthest point in reverse from the stop line that the queue reaches during a signal cycle or gap acceptance cycle. The 95th percentile BoQ, or queue length, represents the threshold below which 95 percent of all observed queue lengths are contained, or conversely, 5 percent of observed queue lengths surpass. This metric, the 95th percentile back of the queue, serves as a valuable indicator of congestion at intersections, offering insights into the maximum queue lengths in worst-case scenarios.

3.6.5 Average Speed

The average travel speed is computed by dividing the travel distance by the average travel time. This average travel time encompasses the impact of intersection delays, interruptions caused by various factors, and overall traffic delay. The average travel speed can be used to evaluate the efficiency and effectiveness of transportation systems, such as roads and intersections. It is an important metric as it provides a quantitative measure of the quality of service of a transportation system and can be used to compare different transportation options.

3.6.6 Performance Index (PI)

A performance index is a composite measure that integrates various performance metrics, including but not limited to delay, the count of stops, and queue length. It is one of the key performance metrics of SIDRA. The performance index is calculated based on a weighted sum of these performance measures, with the weights reflecting the relative importance of each measure. A performance index is a useful tool for transportation planners and engineers, as it provides a single, comprehensive measure of the performance of an intersection and can be used to compare different design options and identify areas for improvement.

The Performance Index is defined as

Equation 3-1

$$PI = Tu + w1.D + w2.K.H/3600 + w3.N'$$

Where,

Tu =total uninterrupted travel time (veh-h/h),

Tu= qa.tu where ‘qa’ is the arrival (demand) flow rate and ‘tu’ is the uninterrupted travel time

D = total delay due to traffic interruption (veh-h/h)

H = total number of effective stops (veh/h)

K = stop penalty

N’ = sum of the queue values (in vehicles) for all lanes, and

w1, w2, w3 = delay weight, stop weight, and queue weight values, respectively

Chapter 4: DATA ANALYSIS

4.1 Intersection Model

The Thapathali intersection is a 4-legged intersection with non-operating traffic signals, rather controlled by traffic police. The two main roads Prashuti Griha Marg – Tripura Marg and Thapathali Road – Kupondole Road intersect to form the Thapathali Intersection. The legs in this intersection are:

- The south leg is Kupondole road towards Kupondole (Kupondole Leg),
- The east leg is Prashuti Griha Marga towards Norvic and Maternity Hospital (Maternity Road Leg),
- The north leg is Thapathali road towards Maitighar (Maitighar Leg),
- The west leg is Tripura Marg towards Tripureshwor (Tripureshwor Leg).

The Kupondole Leg has 5 lanes with an approach length of 530 m, the Maternity Road Leg has 2 lanes with an approach length of 320m, the Maitighar Leg has 4 lanes with an approach length of 520m and the Tripureshwor Leg has 4 lanes with an approach length of 500m. **Figure 4-1** shows the model formed in SIDRA which represents the actual intersection close to reality with the existing number of approach and existing lanes and their widths and lane disciplines.

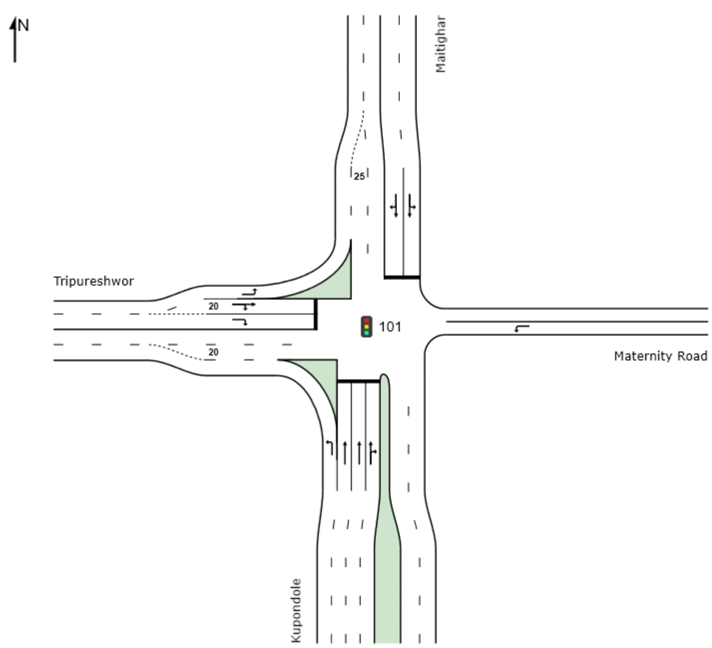


Figure 4-1: Intersection site Layout in SIDRA

4.2 Lane Detailing

The Kupondole leg features 3 approach lanes and 2 exit lanes where left most approach lane serves as a bypass lane for left turn movements. The Maternity Road leg has a single approach lane and a single exit lane with the single approach lane used only for left-turn traffic movements. The Maitighar leg comprises 2 approach lanes and 3 exit lanes whereas the second exit lane is of type short lane. The Tripureshwor leg has 3 approach lanes and 3 exit lanes where the first approach lane is functioning as a bypass lane for left turn movements only and the second approach lane is a short lane acting as a pocket lane to accommodate traffic on the stopped condition while the second exit lane is also of type short lane. The lane control for each lane was configured as "Continuous" if the traffic movement is not controlled either by the device or traffic police or "Signals" if the traffic movement is controlled either by the device or traffic police. The lane configuration, lane discipline, lane geometry, and basic saturation flow for each lane are summarized and shown in **Table 4-1**.

Table 4-1: Summary of Lane Detailing

Leg	Id	Configuration	Type	Control	Length (m)	Width (m)	Discipline	Basic Saturation Flow (tcu/h)
Kupondole Leg	1	Full Length	Bypass (Low Angle)	Continuous	530	3	L	1890
	2	Full Length	Normal	Signal	530	3	T	1800
	3	Full Length	Normal	Signal	530	3	T	1800
	4	Full Length	Normal	Signal	530	3	T+R	1800
Maternity Road Leg	1	Full Length	Normal	Continuous	320	2.75	T+R	1733
Maitighar Leg	1	Full Length	Normal	Signal	520	3.5	L+T	2415
	2	Full Length	Normal	Signal	520	4	T+R	2760
Tripureshwor Leg	1	Full Length	Bypass (Low Angle)	Continuous	500	2.75	L	1733
	2	Short Lane	Normal	Signal	500	3.2	T+R	2016
	4	Full Length	Normal	Signal	500	3.2	R	2016

4.3 Traffic Volume

For Day-1 (weekday), the total traffic volume at the intersection for the morning peak hour (9:15 am to 10:15 am) and evening peak hour (5:45 pm to 6:45 pm) are found to be 5463 PCU and 4835 PCU respectively. Thus, we see at morning peak hours the traffic volume is greater than during the evening peak hours. During the morning peak hour period, Kupondole (South leg) had 2403 PCU, Maternity Road (East leg) had 268 PCU, Maitighar (North leg) had 1404 PCU, and Tripureshwor (West leg) had 1388 PCU which is shown in **Figure 4-2**. During the evening peak hour period, Kupondole (South leg) had 1640 PCU, Maternity Road (East leg) had 323 PCU, Maitighar (North leg) had 1611 PCU, and Tripureshwor (West leg) had 1261 PCU which is shown in **Figure 4-3**.

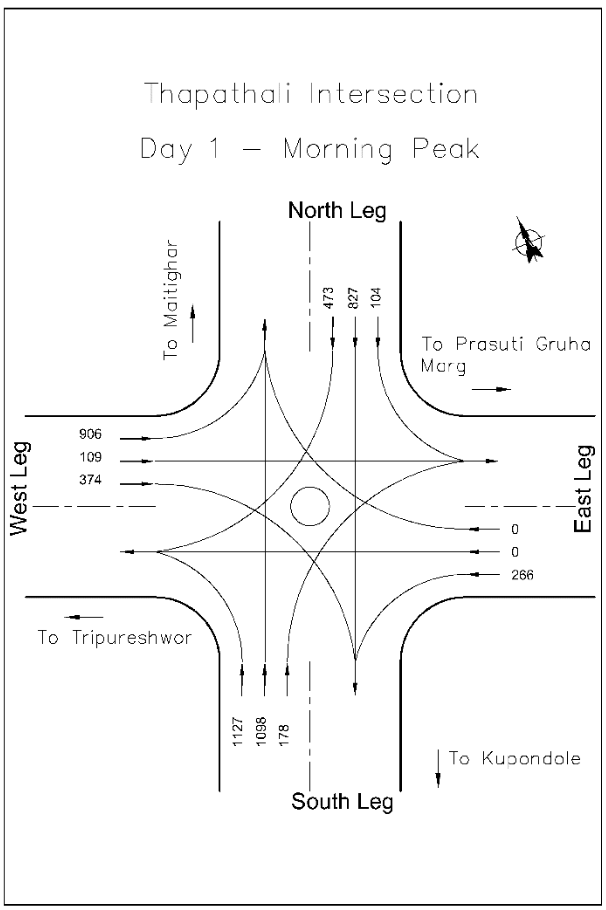


Figure 4-2: Morning Peak Hour (Day-1)

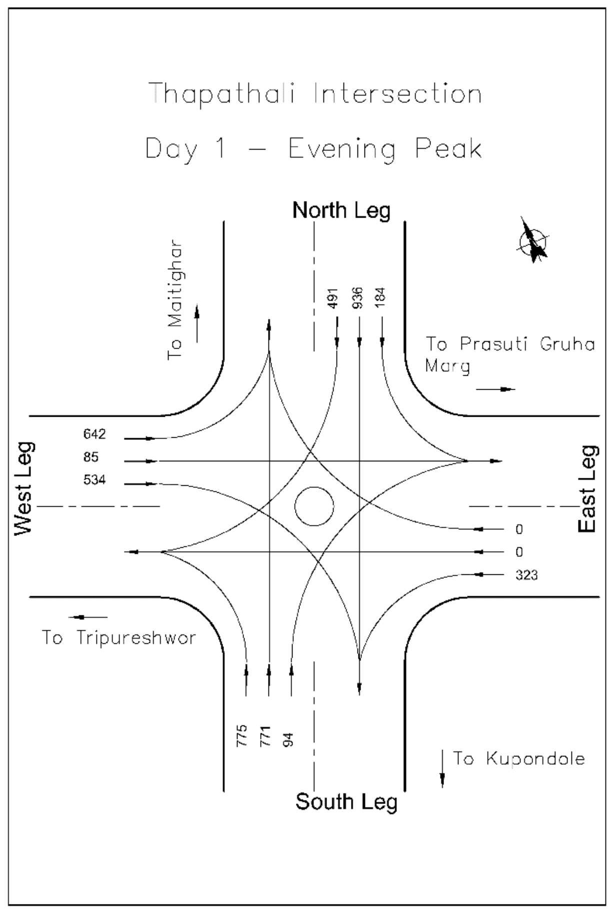


Figure 4-3: Evening Peak Hour (Day-1)

For Day-2 (weekday), the total traffic volume at the intersection for the morning peak hour (9 am to 10 am) and evening peak hour (5 pm to 6 pm) is found to be 5937 PCU and 5086 PCU respectively. Thus, we see at morning peak hours the traffic volume is greater than during the evening peak hours. During the morning peak hour period, Kupondole (South leg) had 2713 PCU, Maternity Road (East leg) had 289 PCU, Maitighar (North leg) had 1432 PCU, and Tripureshwor (West leg) had 1503 PCU which is shown in **Figure 4-4**. During the evening peak hour period, Kupondole (South leg) had 1859 PCU, Maternity Road (East leg) had 331 PCU, Maitighar (North leg) had 1544 PCU, and Tripureshwor (West leg) had 1353 PCU which is shown in **Figure 4-5**.

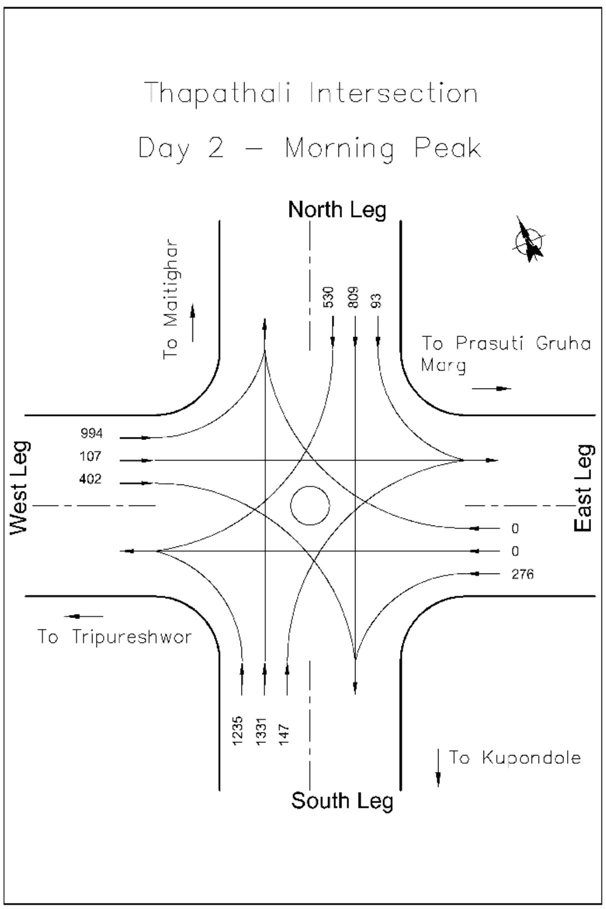


Figure 4-4: Morning Peak Hour (Day-2)

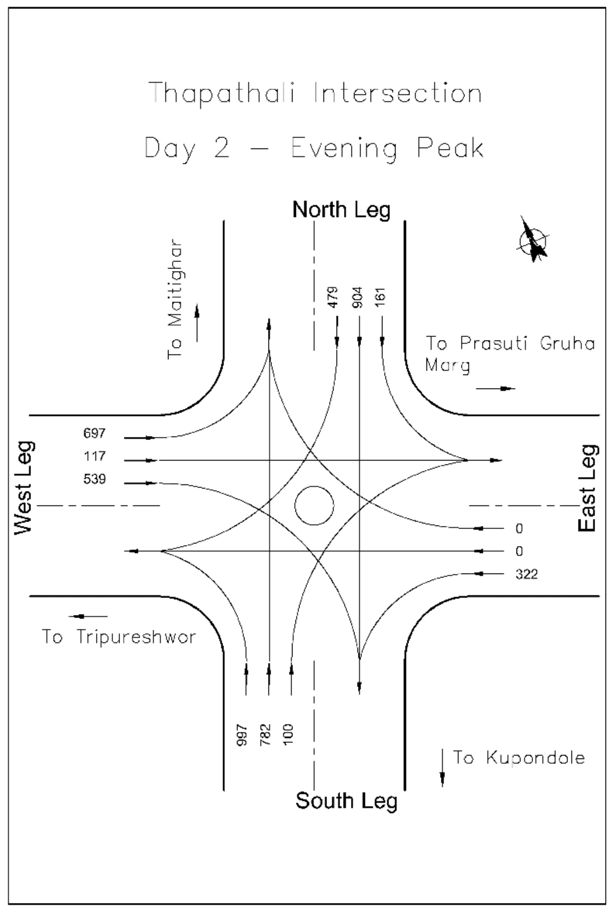


Figure 4-5: Evening Peak Hour (Day-2)

For Day-3 (weekday), the total traffic volume at the intersection for the morning peak hour (9:30 am to 10:30 am) and evening peak hour (5 pm to 6 pm) is found to be 5393 PCU and 4737 PCU respectively. Thus, we see at morning peak hours the traffic volume is greater than during the evening peak hours. During the morning peak hour period, Kupondole (South leg) had 2357 PCU, Maternity Road (East leg) had 279 PCU, Maitighar (North leg) had 1446 PCU, and Tripureshwor (West leg) had 1311 PCU which is shown in **Figure 4-6**. During the evening peak hour period, Kupondole (South leg) had 1847 PCU, Maternity Road (East leg) had 302 PCU, Maitighar (North leg) had 1522 PCU, and Tripureshwor (West leg) had 1067 PCU which is shown in **Figure 4-7**.

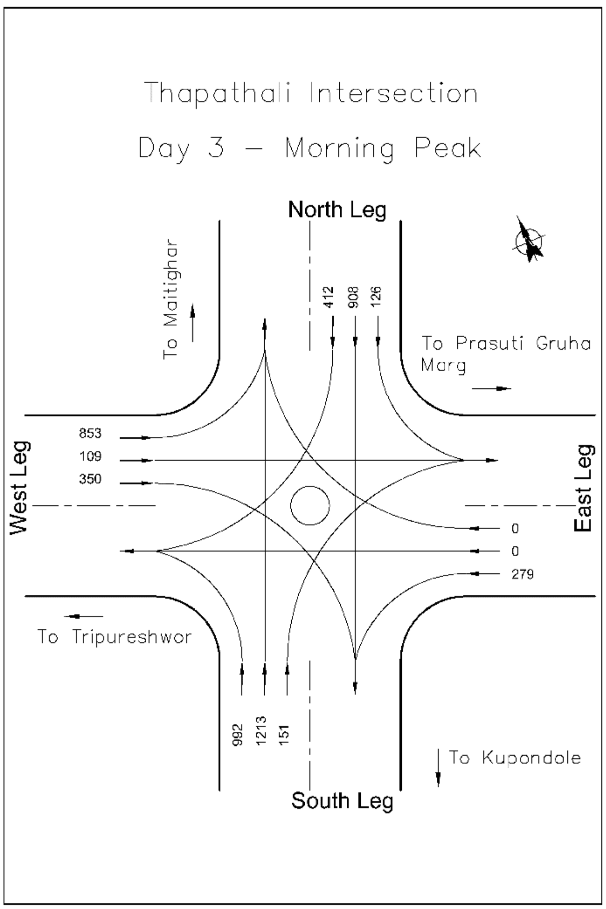


Figure 4-6: Morning Peak Hour (Day-3)

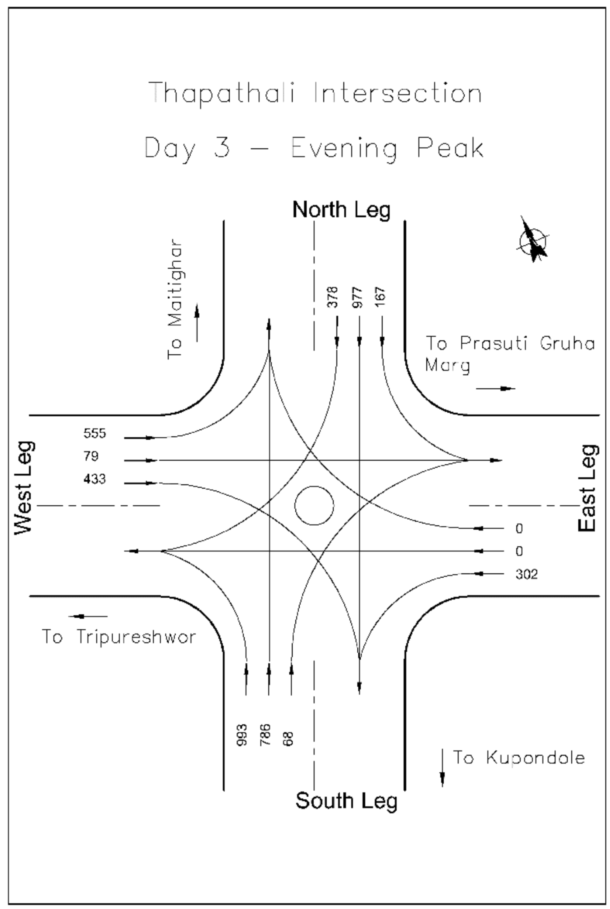


Figure 4-7: Evening Peak Hour (Day-3)

For Day-4 (weekend), the total traffic volume at the intersection for the morning peak hour (10 am to 11 am) and evening peak hour (5:45 pm to 6:45 pm) are found to be 4521 PCU and 4391 PCU respectively. Thus, we see at morning peak hours the traffic volume is greater than during the evening peak hours. During the morning peak hour period, Kupondole (South leg) had 2018 PCU, Maternity Road (East leg) had 125 PCU, Maitighar (North leg) had 1293 PCU, and Tripureshwor (West leg) had 1140 PCU which is shown in **Figure 4-8**. During the evening peak hour period, Kupondole (South leg) had 1795 PCU, Maternity Road (East leg) had 143 PCU, Maitighar (North leg) had 1283 PCU, and Tripureshwor (West leg) had 1171 PCU which is shown in **Figure 4-9**.

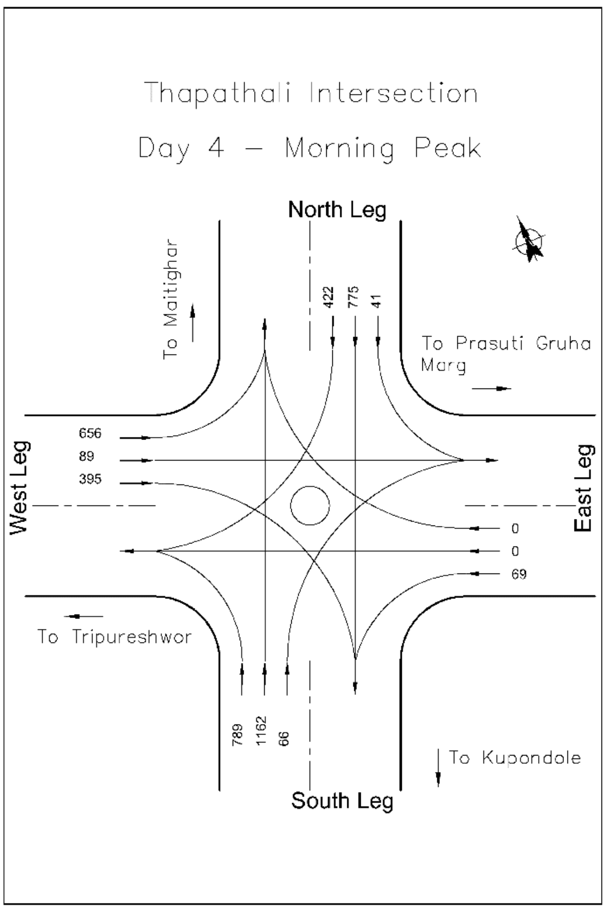


Figure 4-8: Morning Peak Hour (Day-4)

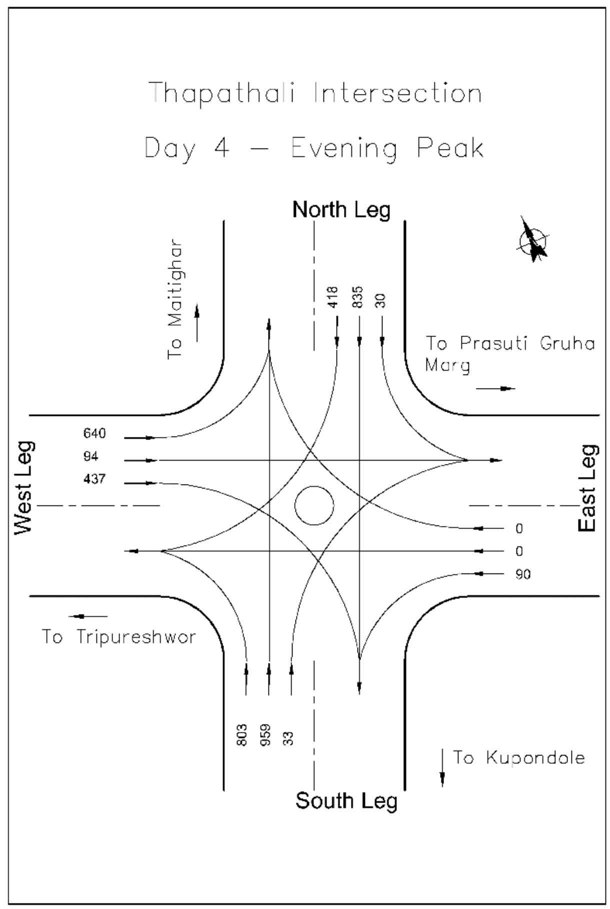


Figure 4-9: Evening Peak Hour (Day-4)

For Day-5 (weekend), the total traffic volume at the intersection for the morning peak hour (9:30 am to 10:30 am) and evening peak hour (5:15 pm to 6:15 pm) are found to be 4874 PCU and 4803 PCU respectively. Thus, we see at morning peak hours the traffic volume is greater than during the other evening peak hours. During the morning peak hour period, Kupondole (South leg) had 1986 PCU, Maternity Road (East leg) had 184 PCU, Maitighar (North leg) had 1514 PCU, and Tripureshwor (West leg) had 1190 PCU which is shown in **Figure 4-10**. During the evening peak hour period, Kupondole (South leg) had 1659 PCU, Maternity Road (East leg) had 214 PCU, Maitighar (North leg) had 1602 PCU, and Tripureshwor (West leg) had 1328 PCU which is shown in **Figure 4-11**.

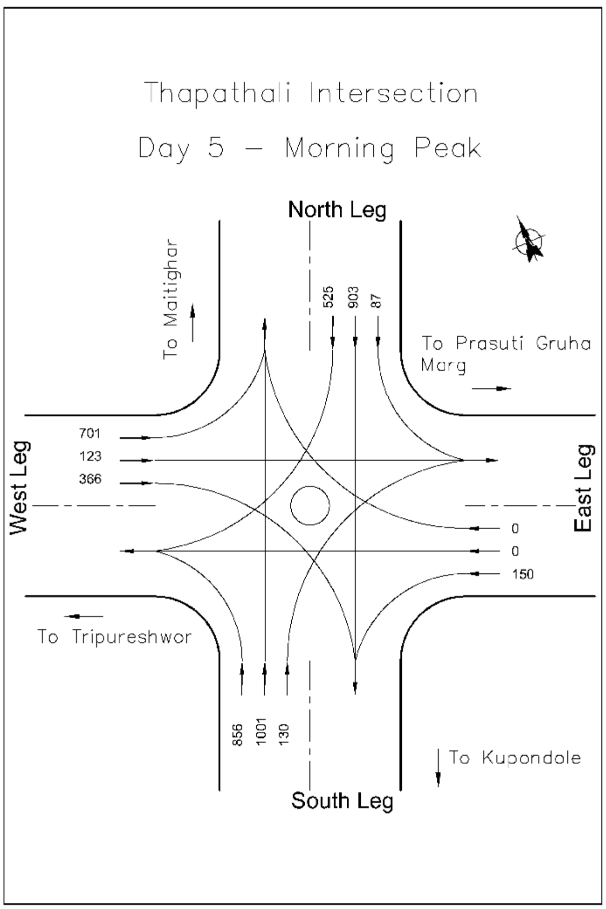


Figure 4-10: Morning Peak Hour (Day-5)

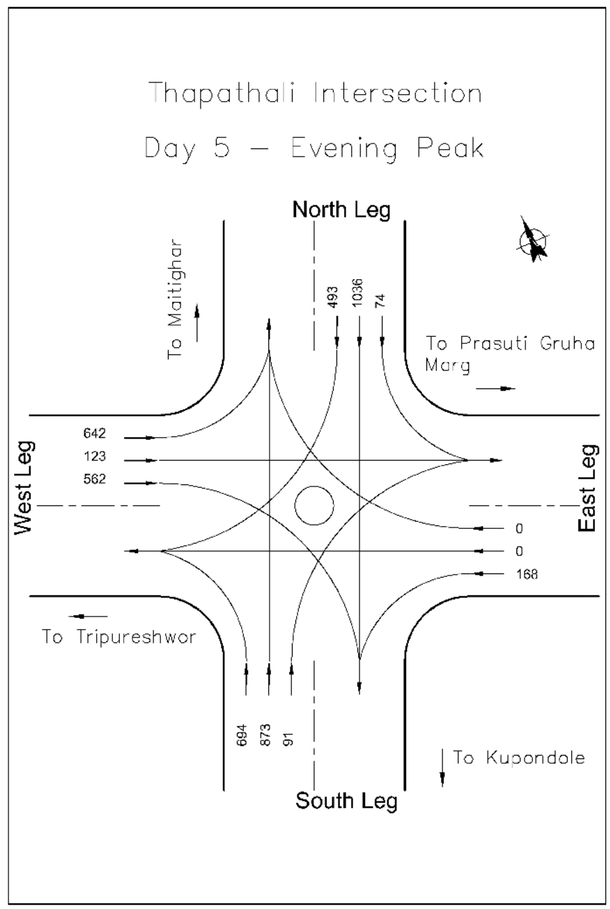


Figure 4-11: Evening Peak Hour (Day-5)

Table 4-2 shows the overall traffic volume in terms of PCU for the peak hours (morning & evening) for Day-1 to Day-5.

Table 4-2: Summary of Total Traffic Volume

Peak Hour		**Day - 1**		**Day - 2**		**Day - 3**		**Day - 4**		**Day - 5**	
		AM	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**
		9:15-10:15	5:45-6:45	9:00-10:00	5:00-6:00	9:30-10:30	5:00-6:00	10:00-11:00	5:45-6:45	9:30-10:30	5:15-6:15
Kupondole	L	1,127	775	1,235	977	992	993	1,118	915	789	803
	T	1,098	771	1,331	782	1,213	786	1,214	779	1,162	959
	R	178	94	147	100	151	68	159	87	66	33
Maternity Road	L	266	323	276	322	279	302	69	90	150	168
Maitighar	L	104	184	93	161	126	167	108	171	41	30
	T	827	936	809	904	908	977	848	939	775	835
	R	473	491	530	479	412	378	472	449	422	418
Tripureshwor	L	906	642	994	697	853	555	918	631	656	640
	T	109	85	107	117	109	79	108	94	89	94
	R	374	534	402	539	350	433	375	502	395	437
Total (PCU)		**5,463**	**4,835**	**5,937**	**5,086**	**5,393**	**4,737**	**5,598**	**4,886**	**4,521**	**4,391**

Upon examination of the provided table, across all five days under consideration, the morning peak hour consistently exhibits a slightly higher vehicular volume compared to the evening peak hour. The variances in volume range from 11.5% to 14.3% on weekdays and 1.5% to 2.9% on weekends. Consequently, the study focuses exclusively on the morning peak hour, characterized by its higher vehicular influx, for the purpose of intersection analysis.

4.4 Pedestrian Volume

The number of pedestrians during the morning rush hour was calculated using the video footage of the intersection. The Maternity Road leg of the intersection had the highest pedestrian count among all the legs, with an average value of 457 during weekdays and 312 during weekends. **Table 4-3** provides information on the pedestrian volume over a period of five days.

Table 4-3: Pedestrian Volume during AM peak hour

Approach Leg	Day 1	Day 2	Day 3	Average	Day 4	Day 5	Average
Kupondole	340	396	316	351	176	336	256
Maternity Road	332	480	560	457	216	408	312
Maitighar	488	344	356	396	140	300	220
Tripureshwor	312	236	248	265	172	268	220

4.5 Vehicle Composition

The identified vehicle classes during the classified vehicle count are Multi-Axle trucks, Heavy trucks, Light trucks, Standard Buses, Mini Buses, Micro Buses, Cars/Taxis, Utility vehicles, Four-Wheel Drives, Motorized three-wheeler (Tempos), and Motorcycles. The analysis of classified vehicle count demonstrated that the primary mode of travel through the intersection is the Motorcycle vehicle class holding 71.4%, 75.5%, 72.4%, 66.6%, and 70.1% composition during Day-1, Day-2, Day-3, Day-4, and Day-5 respectively with a 5 days average composition of 70.58% while Car/Taxi vehicle class has the second highest composition with 14%, 16.8%, 17.7%, 22%, and 19% composition during Day-1, Day-2, Day-3, Day-4, and Day-5 respectively with a 5 days average composition of 17.92%. Bicycle and Rickshaw vehicle classes have been overlooked for the analysis of the intersection. The individual vehicle composition at the intersection for weekdays and weekends is displayed in **Table 4-4**.

Table 4-4: Vehicle Composition at Thapathali Intersection

Vehicle Class	Day-1	Day-2	Day-3	Day-4	Day-5	Average
Multi Axle Truck	0.01%	0.01%	0.00%	0.01%	0.00%	0.01%
Heavy Truck	0.13%	0.06%	0.02%	0.17%	0.09%	0.09%
Light Truck	0.12%	0.11%	0.50%	0.39%	0.27%	0.28%
Standard Bus	1.61%	1.30%	0.35%	1.06%	0.98%	1.06%
Mini Bus	0.19%	0.43%	1.27%	0.30%	0.40%	0.52%
Micro Bus	2.58%	2.22%	1.85%	2.35%	1.62%	2.12%
Car / Taxi	14.05%	16.79%	17.73%	21.99%	19.06%	17.92%
Utility Vehicle	2.05%	1.31%	1.92%	2.36%	2.05%	1.94%
Four Wheel Drive	6.81%	4.14%	2.96%	3.69%	4.23%	4.37%
Motorized Three-Wheeler	1.07%	1.09%	1.00%	1.15%	1.15%	1.09%
Motor Cycle	71.36%	72.53%	72.38%	66.50%	70.13%	70.58%

4.6 Cruise Speeds

The Manual short-base method as described in section **3.4.5.1** in **METHODOLOGY** was implemented to determine the approach cruise speed for each approach leg. The output of the study for the approach legs of the intersection is summarized in **Table 4-5** and the 85th percentile speed, which is considered to exclude extremely fast drivers and gross measuring error is also shown in the same table.

Table 4-5: Summary of Speed Survey for each Approach Legs

Particulars	Kupondole Leg	Maternity Road Leg	Maitighar Leg	Tripureshwor Leg
Minimum Speed (Kmph)	13.0	14.2	17.2	15.7
Maximum Speed (Kmph)	37.9	32.7	37.8	39.1
No. of Samples	96	97	105	104
Mean Speed (Kmph)	26.5	24.7	26.2	29.9
95th Percentile Speed (Kmph)	35.2	29.5	33.1	37.2
85th Percentile Speed (Kmph)	33.0	28.5	30.2	35.0

4.7 Vehicle dimension, Queue Space, Path and Vehicle Calibration Parameters

The vehicle dimension, queue space, path and vehicle calibration parameters adopted from secondary sources for the intersection analysis are different from the default parameters as provided by the SIDRA. The adopted parameters are shown in **Table 4-6**.

Table 4-6: Vehicle Calibration Parameters

Parameters		Vehicle Classes									Source
		Light Trucks	Heavy Trucks	Buses	Mini Buses	Micro Buses	Cars	Jeeps	Tempos	Motor Cycles	
Adopted PCU		1.5	3.0	3.0	2.5	1.5	1	1	0.75	0.25	KVITSP
Queue Space (m)		7.2	9.5	12.35	7.1	6.0	4.4	5.0	4.0	2	(Bajracharya & Dhungel, 2022)
Vehicle Length (m)		6.2	8	10.85	6.6	5.4	4.0	4.6	3.6	1.8	
Vehicle Occupancy (person/veh)		2	2	40	13	13	2	2	9.2	1	KVITSP
Turning Vehicle Factor	Left Turn	1.05	1.09	1.09	1.05	1.05	1.05	1.05	1.05	1.05	SIDRA User Guide Recommendation
	Through	1	1	1	1		1	1	1	1	
	Right Turn	1.05	1.09	1.09	1.05	1.05	1.0	1.05	1.05	1.05	
Gap Acceptance Factor		1	1.5	1.5	1	1	1	1	1	1	SIDRA User Guide
Opposing Vehicle Factor		1	1.5	1.5	1	1	1	1	1	0.5	
Start Loss (sec)		2	2	2	2	2	2	2	2	2	HCM 2010
End Gain (sec)		2	2	2	2	2	2	2	2	2	

4.8 Phasing & Signal timing

The phase timing for peak hour and off-peak periods for each day were determined through the extraction of data from video recordings of traffic flow during various events, resulting in the calculation of an average value for each phase. The vehicular movements allowed in each of the phase mentioned below are previously shown in **Table 3-3**. The observations for all 5 phases over 5 days are presented in Appendix C. A summary of the peak hour phase timing for each day, from Day-1 to Day-5, can be found in **Table 4-7** to **Table 4-11** respectively.

Table 4-7: Summary of Phase Timing for Day-1

Number of Events	Phases	Occurrences	Total Duration	Avg. Duration per Cycle	Seconds
8	P1	43	0:09:50	0:01:14	74
	P2	44	0:16:10	0:02:01	121
	P3	40	0:09:41	0:01:13	73
	P4	38	0:07:39	0:00:57	57
	P5	8	0:15:31	0:01:56	116
			0:58:51	0:07:21	441

Table 4-8: Summary of Phase Timing for Day-2

Number of Events	Phases	Occurrences	Total Duration	Avg. Duration per Cycle	Seconds
9	P1	49	0:09:21	0:01:02	62
	P2	53	0:16:39	0:01:51	111
	P3	32	0:08:38	0:00:58	58
	P4	38	0:07:01	0:00:47	47
	P5	9	0:15:26	0:01:43	103
			0:57:05	0:06:21	381

Table 4-9: Summary of Phase Timing for Day-3

Number of Events	Phases	Occurrences	Total Duration	Avg. Duration per Cycle	Seconds
7	P1	45	0:09:44	0:01:23	83
	P2	46	0:18:37	0:02:40	160
	P3	26	0:06:11	0:00:53	53
	P4	28	0:08:59	0:01:17	77
	P5	7	0:16:17	0:02:20	140
			0:59:48	0:08:33	513

Table 4-10: Summary of Phase Timing for Day-4

Number of Events	Phases	Occurrences	Total Duration	Avg. Duration per Phase	Seconds
40	P1	33	0:05:48	0:00:09	9
	P2	55	0:16:57	0:00:25	25
	P3	40	0:11:13	0:00:17	17
	P4	32	0:08:17	0:00:12	12
	P5	42	0:18:03	0:00:27	27
			1:00:18	0:01:30	90

Table 4-11: Summary of Phase Timing for Day-5

Number of Events	Phases	Occurrences	Total Duration	Avg. Duration per Phase	Seconds
28	P1	38	0:08:00	0:00:17	74
	P2	48	0:16:04	0:00:34	121
	P3	37	0:12:49	0:00:27	73
	P4	24	0:05:37	0:00:12	57
	P5	28	0:18:15	0:00:39	116
			1:00:45	0:02:10	130

4.9 Calibration and Validation of the Model using BoQ.

A comparison between the observed and simulated queue lengths is presented in **Table 4-12**. From the table, it is implied that for all 5 days both the observed and simulated queue lengths are within the 20% range. The validation of the simulation model is established when the percentage difference between these queue lengths is within 20%. Validation of the simulation model can be confirmed from the same table which compares the observed and simulated queue lengths.

Table 4-12: Queue Length Comparison

Day	Leg	Mean BoQ (m)	95th Percentile BoQ		% Difference
			Observed (m)	Simulated (m)	
1	Kupondole	323	415	438	5.6%
	Maitighar	382	438	425	3.0%
	Tripureshwor	252	388	365	5.8%
2	Kupondole	344	463	499	7.7%
	Maitighar	249	350	361	3.3%
	Tripureshwor	255	365	373	2.1%
3	Kupondole	475	543	501	7.8%
	Maitighar	453	544	529	2.7%
	Tripureshwor	375	448	423	5.7%
4	Kupondole	74	93	87	5.9%
	Maitighar	51	78	81	3.8%
	Tripureshwor	106	171	157	8.1%
5	Kupondole	244	330	365	10.5%
	Maitighar	327	532	518	2.7%
	Tripureshwor	317	494	506	2.4%

4.10 Evaluation of Intersection's current performance during weekdays

Based on the numerous data collected from primary and secondary sources, the model of the Thapathali intersection was developed for the morning peak hour with adequate calibration and validation. The average of 3 week-days vehicle count and phase timing for the morning peak hour was used to prepare the week-day model. After processing the model with SIDRA, various performance statistics were extracted. The performance statistics for the weekday model of the Thapathali intersection at the present are summarized in **Table 4-13**.

Table 4-13: Performance Statistics of the Intersection during weekdays at present

Turn	Demand Flows (veh/h)	DoS (v/c)	Average Delay (sec)	LoS	95% BoQ		Average Speed (kmph)
					Vehicles (veh)	Distance (m)	
South: Kupondole Leg							
L	2730	0.658	0.1	A	0	0	33.4
T	2628	0.746	103.8	F	245.6	666.7	17.3
R	363	1.448	351	F	101.6	265.2	6.2
Total	5721	1.448	69.9	E	245.6	666.7	20.1
East: Maternity Road							
L	639	0.178	0	A	0	0	28.5
Total	639	0.178	0	A	0	0	28.5
North: Maitighar Leg							
L	232	0.59	17.5	B	133.3	359.9	26
T	1842	0.59	17.5	B	133.3	359.9	26.5
R	1069	0.668	145.8	F	206.2	535.3	13.8
Total	3134	0.668	61.1	E	206.2	535.3	20.2
West: Tripureshwor							
L	2161	0.6	0.1	A	0	0	35.4
T	277	2.215	658.4	F	89.2	214.3	3.6
R	799	2.191	618.6	F	254.7	694.5	4.6
Total	3238	2.215	209.1	F	254.7	694.5	10.7
All Vehicles	12740	2.215	99.6	F	254.7	694.5	16.6

During week-days, the total demand flow is 12740 veh/h with a degree of saturation of 2.215 and an average delay per vehicle of 99 seconds. The overall intersection has a level of service of F as the worst performing approach is Tripureshwor leg with LoS of F, the highest control delay of 209.1 sec, and the highest 95^{th} percentile BoQ of 694.5 m.

	Approaches				Intersection
	South	East	North	West	
LOS	E	A	E	F	F

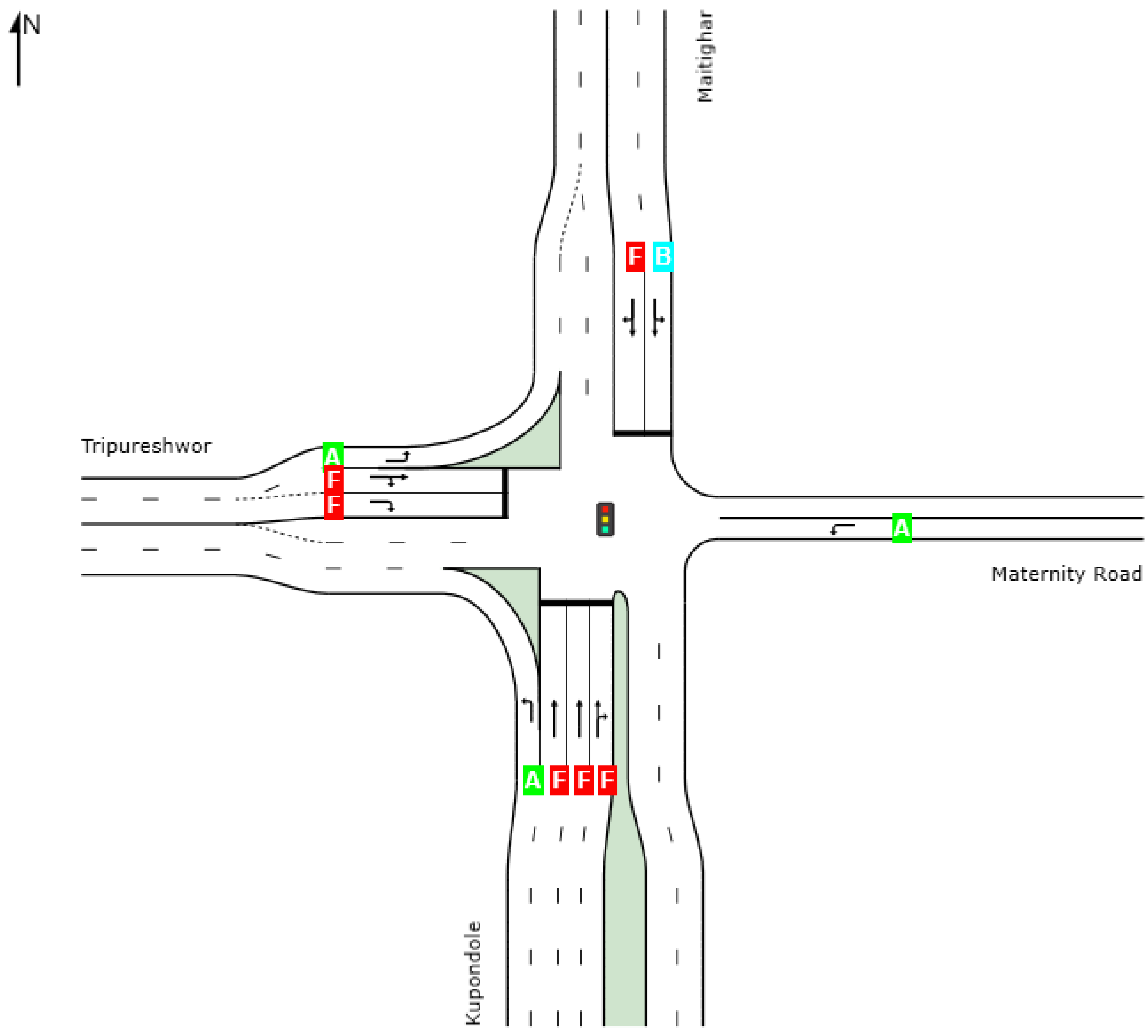
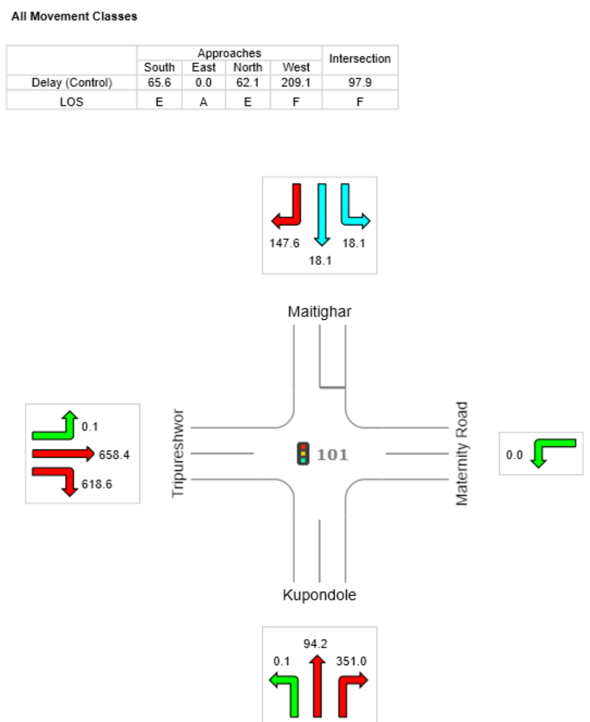


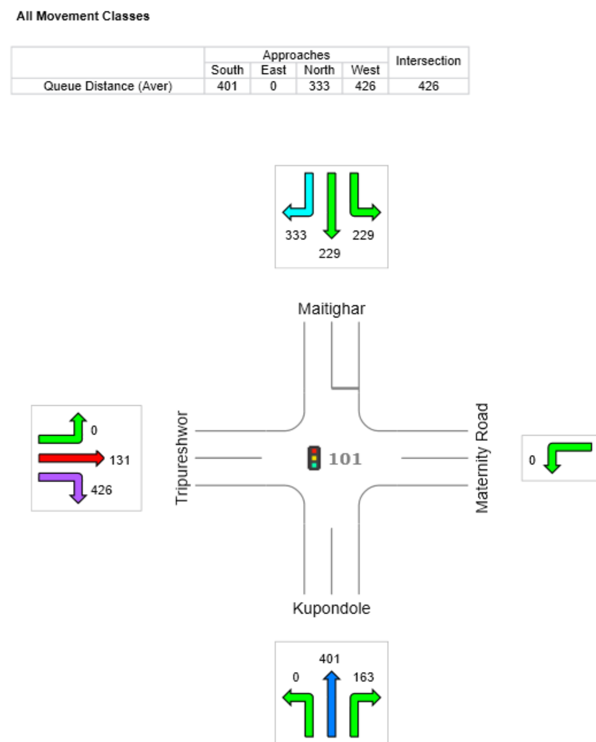
Figure 4-12: LoS of the Thapathali Intersection during weekdays at present



All Movement Classes

	Approaches				Intersection
	South	East	North	West	
Delay (Control)	65.6	0.0	62.1	209.1	97.9
LOS	E	A	E	F	F

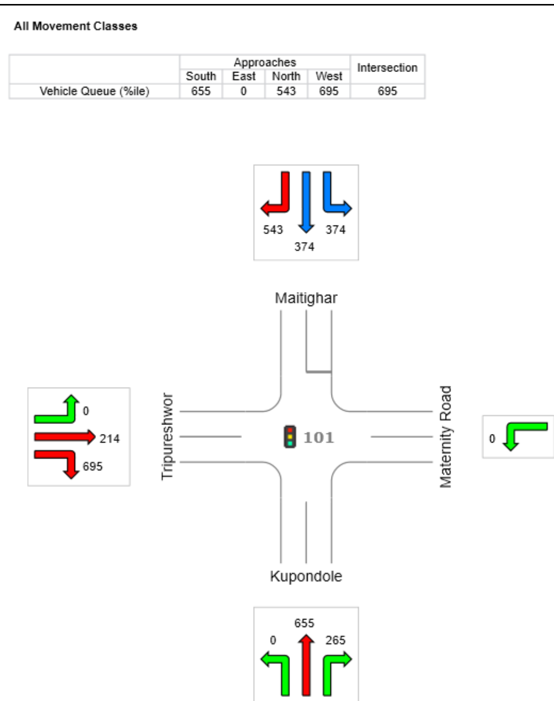
Figure 4-13: Average Delay (sec) – Weekday



All Movement Classes

	Approaches				Intersection
	South	East	North	West	
Queue Distance (Aver)	401	0	333	426	426

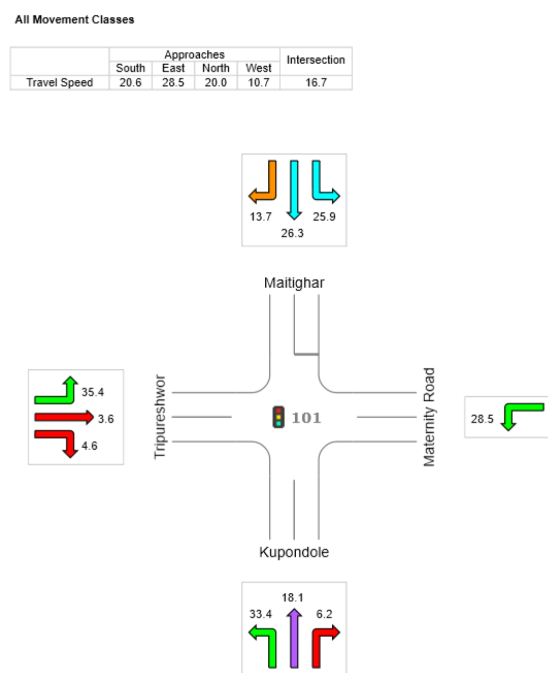
Figure 4-14: Average Queue (m) - Weekday



All Movement Classes

	Approaches				Intersection
	South	East	North	West	
Vehicle Queue (%ile)	655	0	543	695	695

Figure 4-15: 95th BoQ (m) - Weekday



All Movement Classes

	Approaches				Intersection
	South	East	North	West	
Travel Speed	20.6	28.5	20.0	10.7	16.7

Figure 4-16: Average Speed (kmph) - Weekday

4.11 Evaluation of Intersection's current performance during weekends

Similar to week days, the average of 2 weekend days' vehicle counts and phase timing for the morning peak hour was used to prepare the weekend model. After processing the model with SIDRA, various performance statistics were extracted. The performance statistics for the weekend model of the intersection at the present are summarized in **Table 4-14**.

Table 4-14: Performance Statistics of the intersection during weekends at present

Turn	Demand Flows (veh/h)	DoS (v/c)	Average Delay (sec)	LoS	95% BoQ		Average Speed (kmph)
					Vehicles (veh)	Distance (m)	
South: Kupondole Leg							
L	1789	0.476	0	A	0	0	33.5
T	2299	0.799	32.9	C	60.3	164.1	25.7
R	227	0.877	74.3	E	14.9	38.5	18.3
Total	4314	0.877	21.4	C	60.3	164.1	27.9
East: Maternity Road							
L	257	0.071	0	A	0	0	28.5
Total	257	0.071	0	A	0	0	28.5
North: Maitighar Leg							
L	145	0.6	5.5	A	38.6	108.7	29
T	1668	0.6	5.5	A	48.2	128.3	28.9
R	1020	0.595	32.6	C	48.2	128.3	23.9
Total	2834	0.595	15.4	B	48.2	128.3	26.9
West: Tripureshwor							
L	1449	0.437	0	A	0	0	35.4
T	268	1.353	208	F	52.9	136.8	9.9
R	761	1.353	203.8	F	60.5	170	11.7
Total	2479	1.353	85.1	F	60.5	170	18.9
All Vehicles	9884	1.353	35.1	D	60.5	170	24.7

During week-days, the total demand flow is 9884 veh/h with a degree of saturation of 1.353 and an average delay per vehicle of 35.1 seconds. The overall intersection has a level of service of D as the worst performing approach is Tripureshwor leg with LoS of F, highest control delay of 60.5 sec, and highest 95th percentile BoQ of 170 m.

	Approaches				Intersection
	South	East	North	West	
LOS	C	A	B	F	D

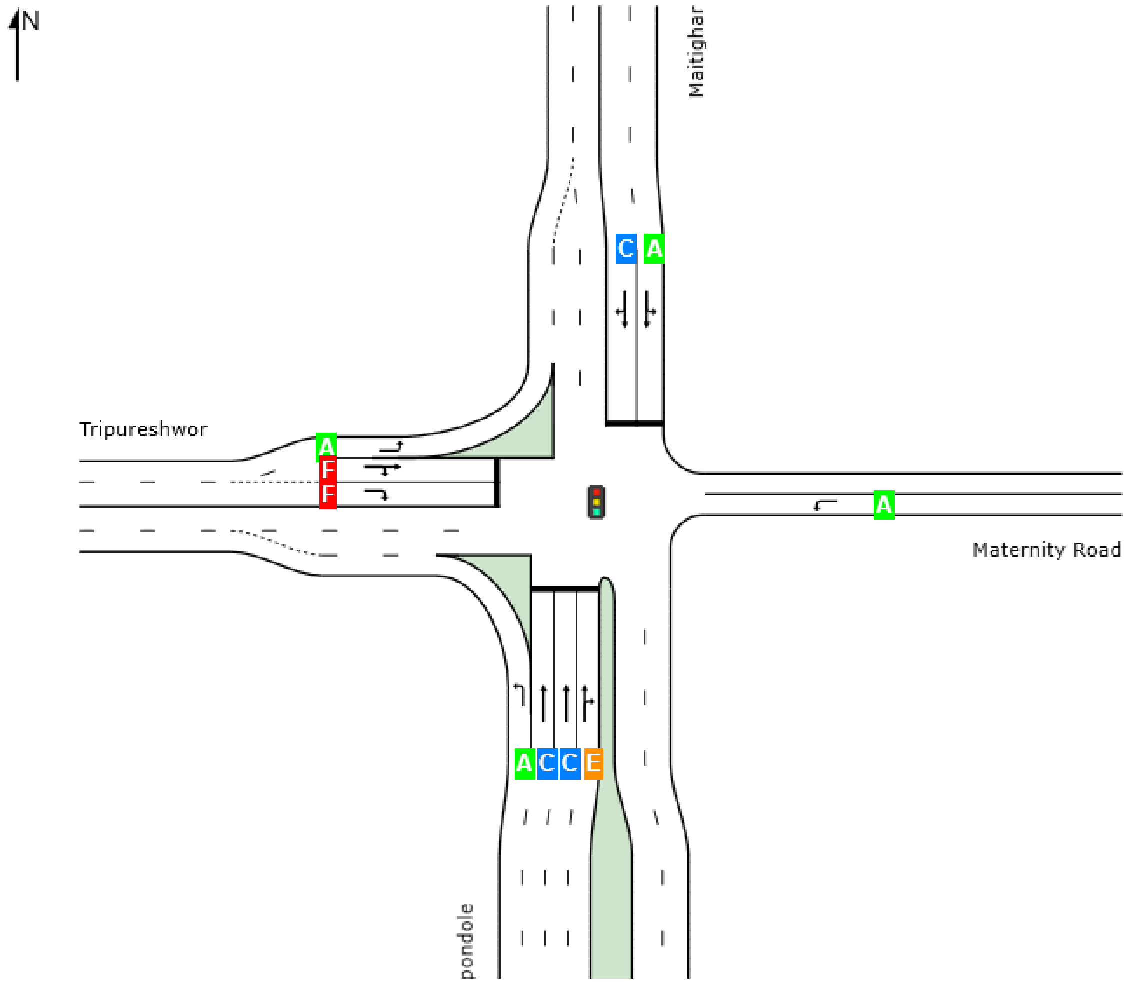


Figure 4-17: LoS of the Thapathali Intersection during weekends at present

	Approaches				Intersection
	South	East	North	West	
Delay (Control)	21.4	0.0	15.4	85.1	35.1
LOS	C	A	B	F	D

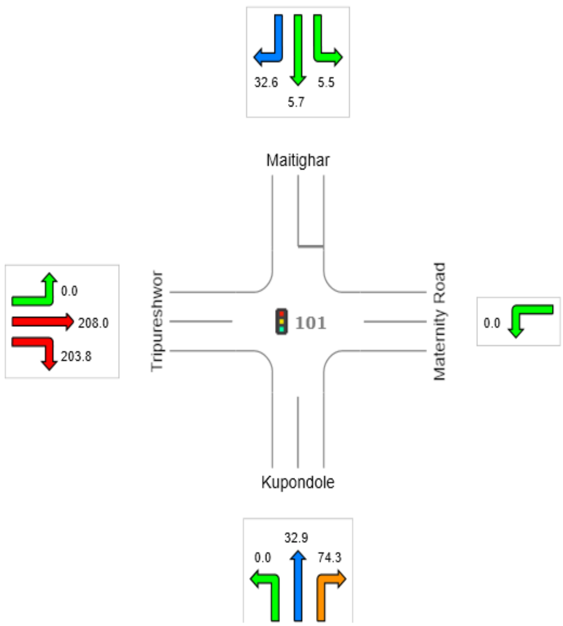


Figure 4-18: Average Delay (sec) – Weekend

	Approaches				Intersection
	South	East	North	West	
Queue Distance (Aver)	101	0	79	104	104

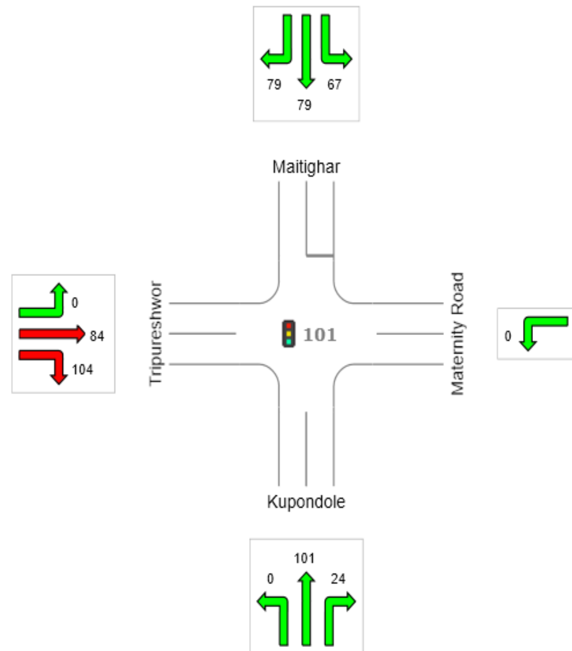


Figure 4-19: Average Queue (m) - Weekend

	Approaches				Intersection
	South	East	North	West	
Vehicle Queue (%ile)	164	0	128	170	170

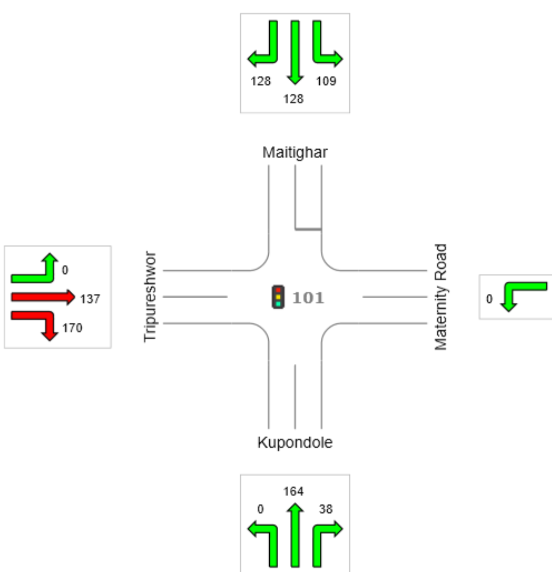


Figure 4-20: 95th BoQ (m) - Weekend

	Approaches				Intersection
	South	East	North	West	
Travel Speed	27.9	28.5	26.9	18.9	24.7

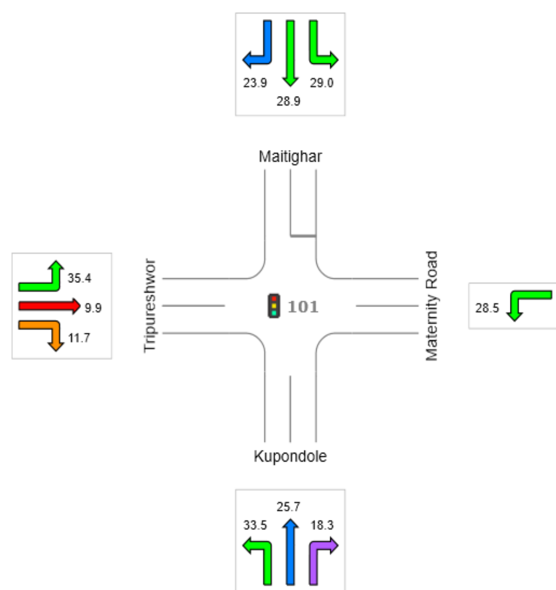


Figure 4-21: Average Speed (kmph) - Weekend

4.12 Evaluation of Intersection's performance under various Lane and Phase reconfiguration options for the weekday model

From the performance statistics obtained for the weekday model of the Intersection, it is quite clear that the intersection has poor performance with higher DoS, higher delay, LoS of F, longer queue lengths, and lower travel speeds. Thus, to improve the performance of the intersection during weekdays following lane and phase reconfiguration options under program-generated optimum signal time (Dhakal, Tiwari, & Luitel, 2023) were analyzed. The phase configurations suggested by SIDRA along with generally used configurations in Kathmandu for four-legged intersection have been used for analysis.

4.12.1 Lane Configuration LC1 with Phase Reconfigurations

The Kupondole leg was reconfigured in terms of lane discipline. Three approach lanes with exclusive through turn, share through and right turns, and exclusive right turns were proposed without altering the widths of approach or exit lanes. The layout of the intersection under lane configuration LC1 is shown in **Figure 4-22**.

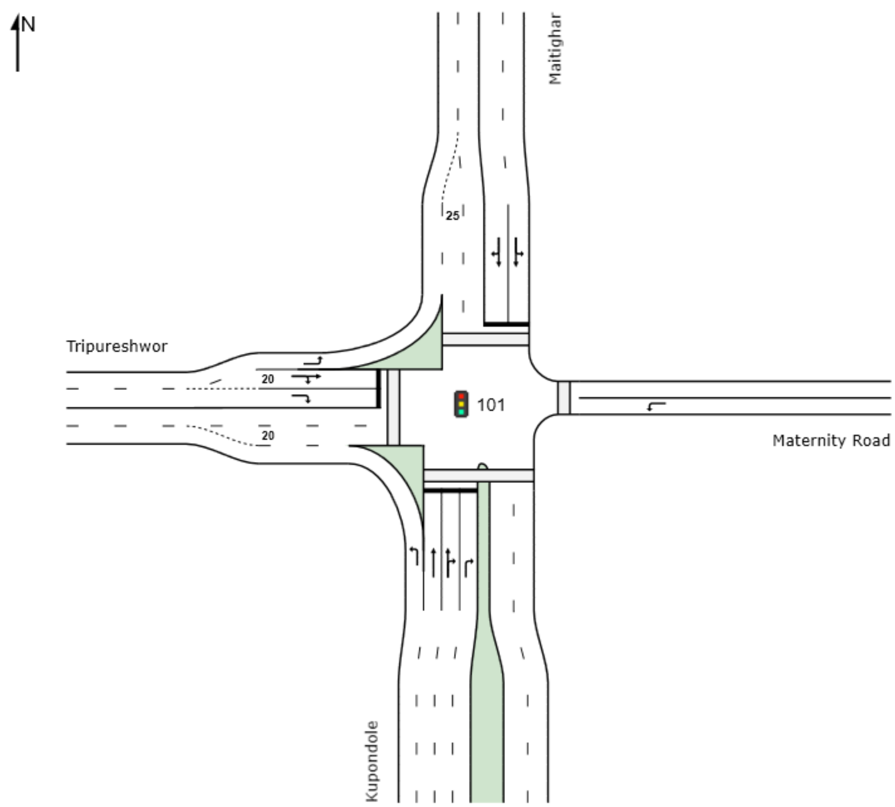


Figure 4-22: Layout of the Intersection under Lane Configuration 1

Phase reconfigurations under lane configuration (LC1) analyzed for the intersection weekday model are shown in figures from **Figure 4-23** to **Figure 4-25** respectively.

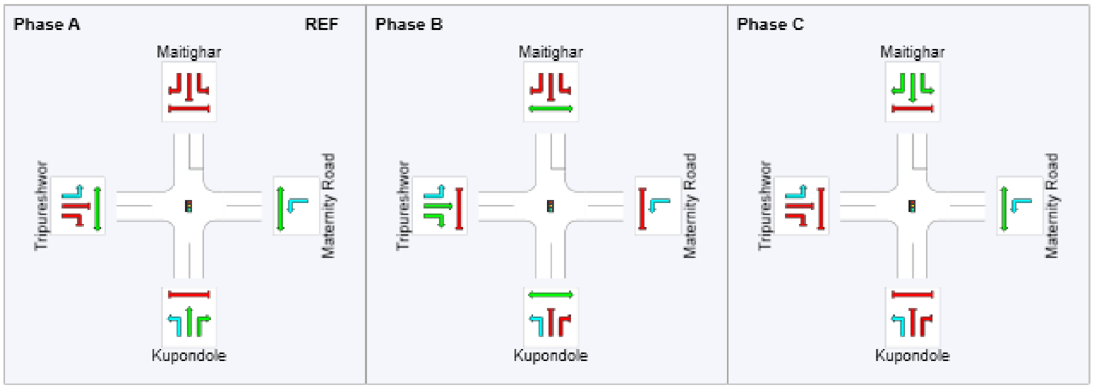


Figure 4-23: Option LC1-3P: 3 Phase Configuration

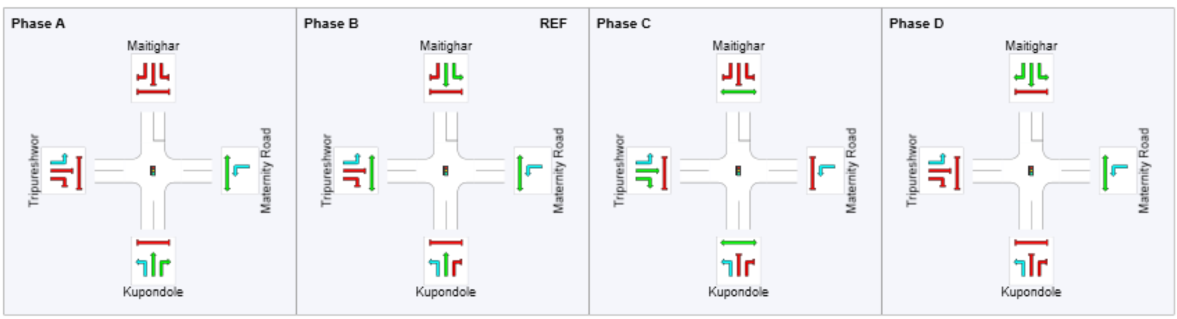


Figure 4-24: Option LC1-4P: 4 Phase Configuration

Figure 4-25: Option LC1-5P: 5 Phase Configuration

4.12.2 Lane Configuration LC2 with Phase Reconfigurations

The Maitighar leg was reconfigured in terms of lane widths and lane discipline. Three approach lanes with an exclusive left turn, share through and right turns and exclusive right turn were proposed and the widths of exit lanes were reduced to accommodate the addition of the third lane. The exclusive left turn lane was not controlled and the control type was set to continuous rather than signals. The layout of the intersection under lane configuration LC2 is shown in **Figure 4-26**.

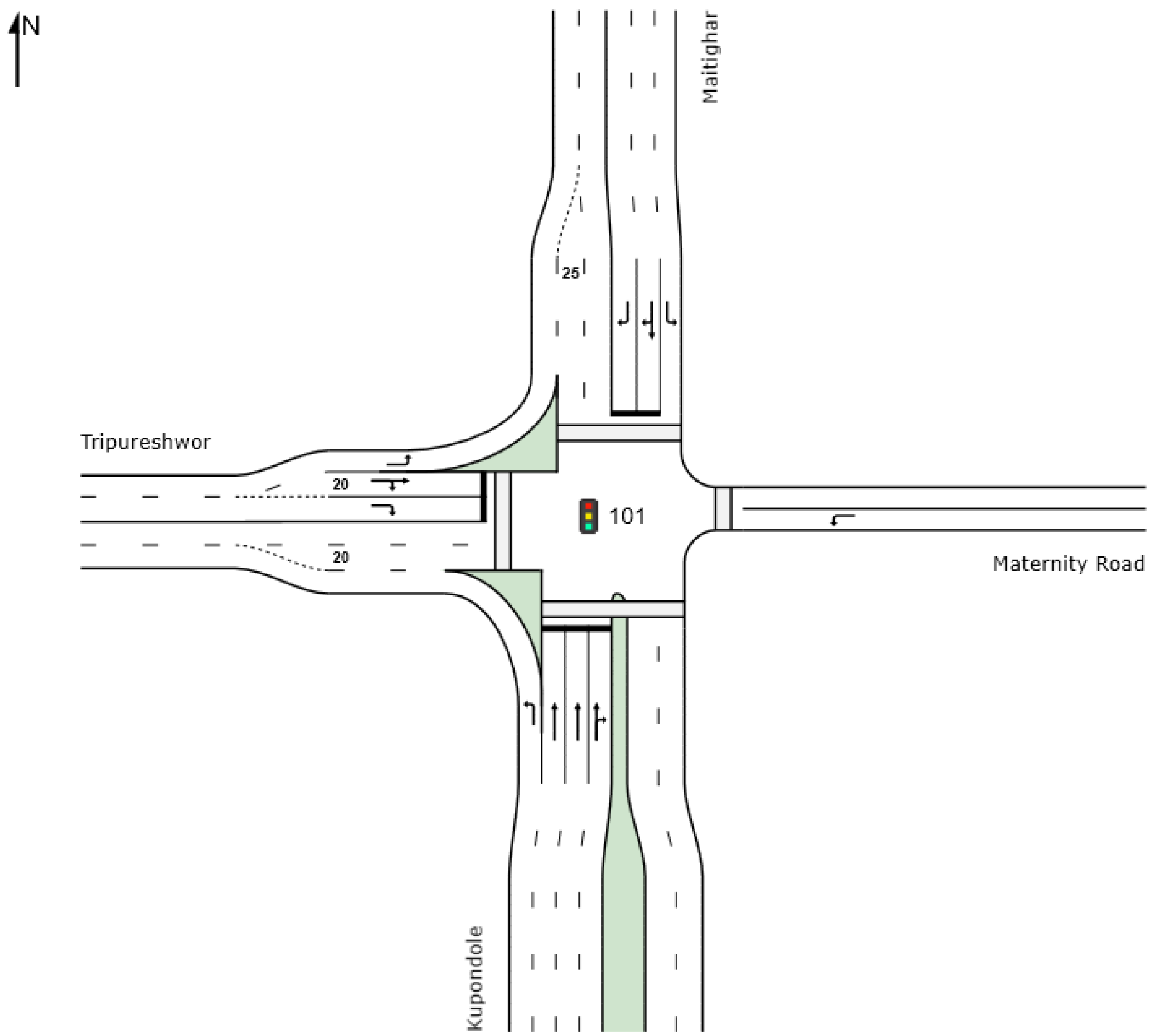


Figure 4-26: Layout of the Intersection under Lane Configuration 2

Phase reconfigurations under lane configuration (LC2) analyzed for the intersection weekday model are shown in figures from **Figure 4-27** to **Figure 4-29** respectively.

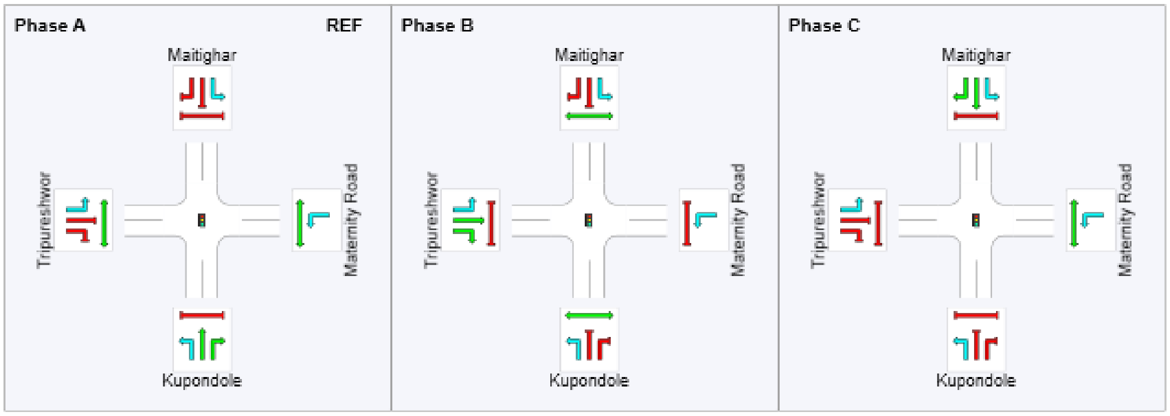


Figure 4-27: Option LC2-3P: 3 Phase Configuration

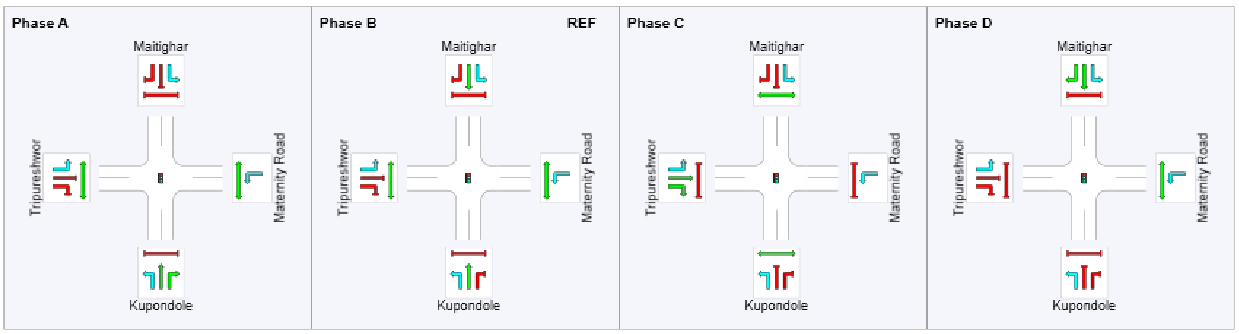


Figure 4-28: Option LC2-4P: 4 Phase Configuration

Figure 4-29: Option LC2-5P: 5 Phase Designed Configuration

4.12.3 Lane Configuration LC3 with Phase Reconfigurations

The Tripureshwor leg was reconfigured in terms of lane widths and lane discipline. A short lane was added to the approach lane and the existing short lane was removed from the exit lanes. Three approach lanes with an exclusive through turn short lane, share through and right turns full-length lane and exclusive right turn short lane were proposed. The layout of the intersection under lane configuration LC3 is shown in **Figure 4-30**.

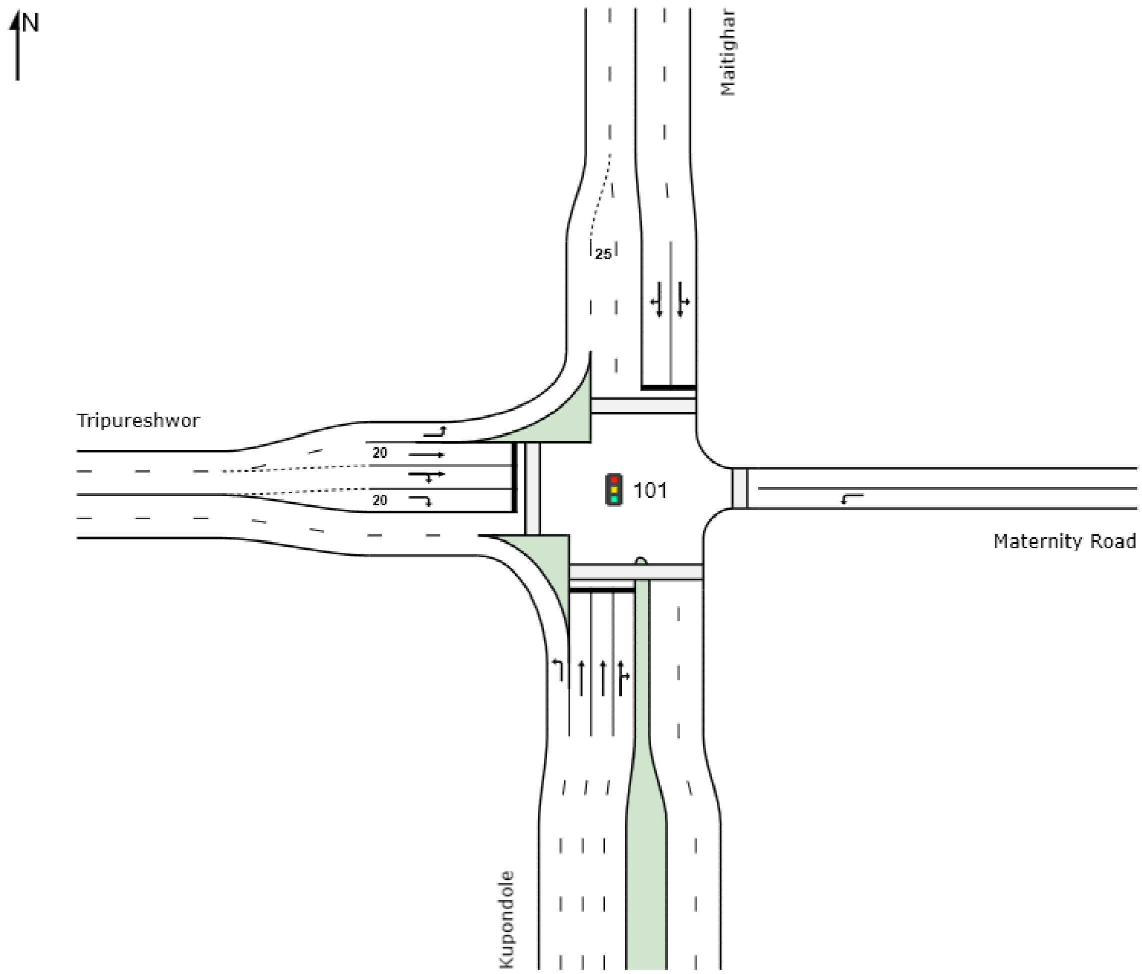


Figure 4-30: Layout of the Intersection under Lane Configuration 3

Phase reconfigurations under lane configuration (LC3) analyzed for the intersection weekday model are shown in figures from **Figure 4-31** to **Figure 4-33** respectively.

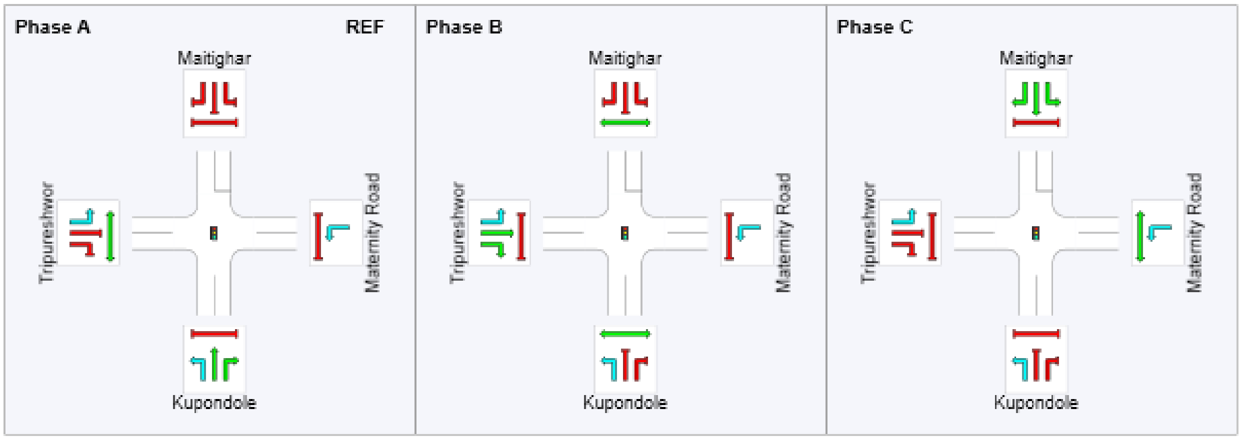


Figure 4-31: Option LC3-3P: 3 Phase Configuration

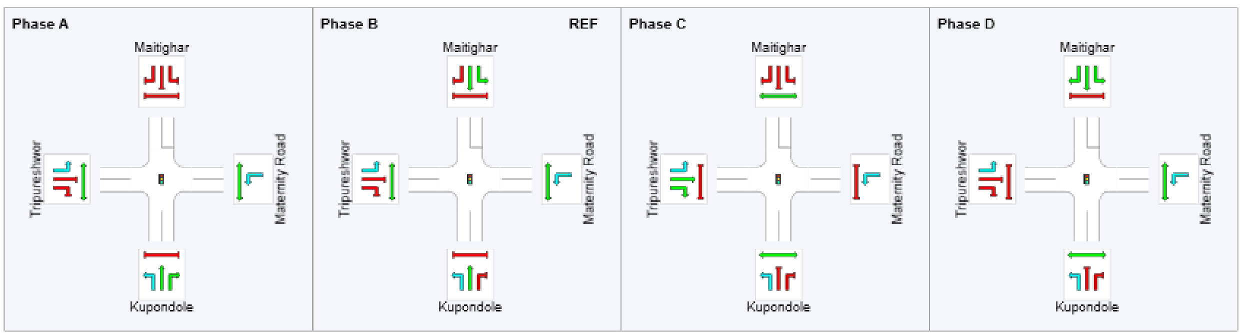


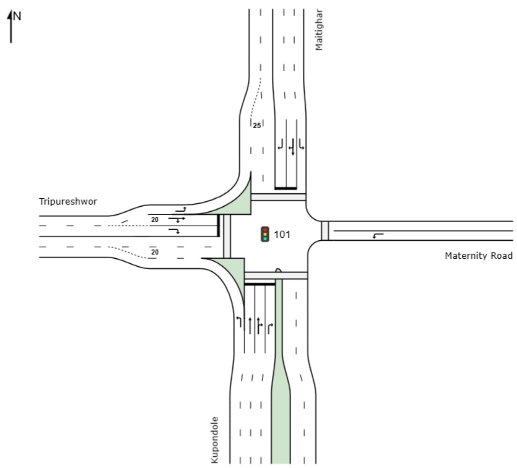
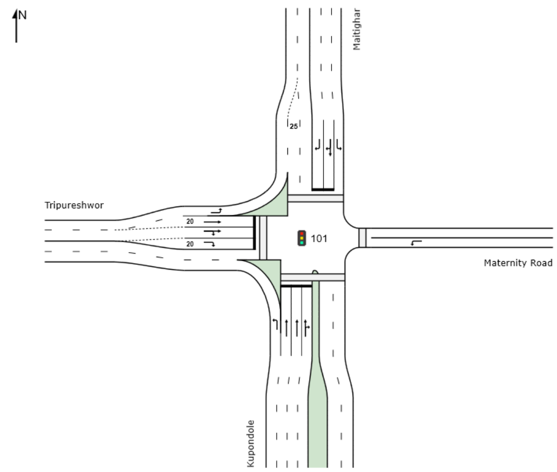
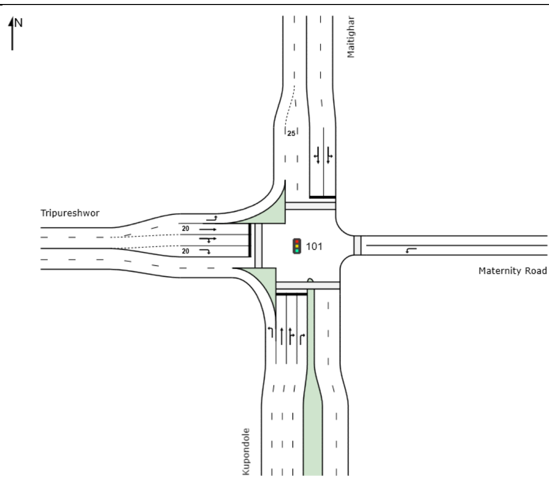
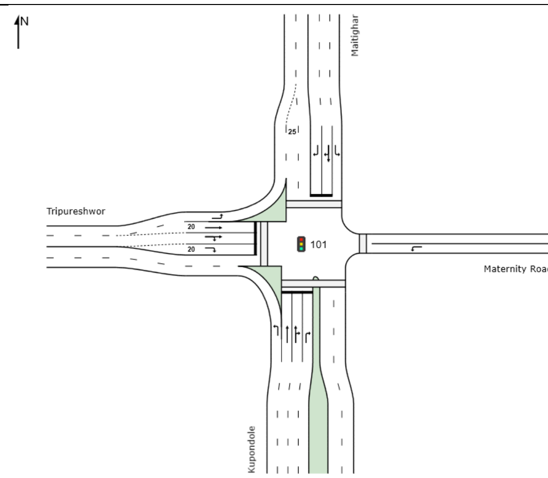
Figure 4-32: Option LC3-4P: 4 Phase Configuration

Figure 4-33: Option LC3-5P: 5 Phase Configuration

4.12.4 Lane Configuration LC4, LC5, LC6, LC7 with Phase Reconfigurations

The lane configuration LC4 to LC7 basically are various combinations of lane configuration LC1, LC2 & LC3. The layout of the intersection under lane configuration LC4 to LC7 are shown in **Table 4-15**.

Table 4-15: Layout of the Intersection under LC4 to LC7

 Combination of LC1 & LC2	 Combination of LC2 & LC3
 Combination of LC3 & LC1	 Combination of LC1, LC2 & LC3

4.12.5 Comparison of various Options for the weekday model

Various performance statistics were compared for all the options of the weekday model and based on the performance index the best option was selected.

Table 4-16: Comparing weekday model performance across options.

Option	**Cycle Time**	**Performance Index**	**DoS**	**Average Delay**	**LoS**	**95% Back of Queue**		**Average Speed**
						Vehicles	**Distance**	
	sec		**v/c**	**sec**		**veh**	**m**	**km/h**
LC1-3P	100	3974.4	1.359	95	F	211.6	574.4	17.4
LC1-4P	90	2622.9	1.235	50.7	D	177.1	480.7	22.3
LC1-5P	150	3326.8	1.284	54.1	D	247.2	671.1	21.7
LC2-3P	90	2743.1	1.317	76.8	E	174.5	470.4	19.1
LC2-4P	90	2444.0	1.244	61.7	E	135.5	365.3	20.7
LC2-5P	150	2393.7	1.047	33	C	124	334.1	24.6
LC3-3P	90	2085.2	0.973	27.7	C	92.9	244.7	26.2
LC3-4P	90	1888.8	0.978	24.1	C	78.6	206.1	26.9
LC3-5P	130	2496.7	1.046	37.5	D	110.7	298.9	23.7
LC4-3P	110	3813.6	1.564	112.8	F	261.3	709.2	16
LC4-4P	100	2937.4	1.325	72	E	204.9	556.1	19.4
LC4-5P	150	3597.7	1.428	85.8	F	282.3	766.4	17.8
LC5-3P	100	2496.3	1.244	62.5	E	168.8	455	20.7
LC5-4P	100	2224.3	1.167	52.2	D	123.5	332.8	21.8
LC5-5P	150	2285.2	1.047	31.7	C	124	334.1	24.8
LC6-3P	110	3718.9	1.293	79.7	E	220.2	597.9	18.8
LC6-4P	90	2412.8	1.216	44.3	D	182.4	495.1	23.2
LC6-5P	150	3355.3	1.312	57.3	E	269.3	731.1	21.3
LC7-3P	120	3712.4	1.531	104.2	F	279.9	759.8	16.6
LC7-4P	110	2959.0	1.263	69.8	E	208.5	565.9	19.6
LC7-5P	140	3997.0	1.542	117.6	F	304.8	827.3	15.4

Option LC3-4P with the least performance index of 1888.8 is chosen as the best option for the weekday. This option has a degree of saturation of 0.978, an average delay of 26.9 sec, LoS of C, 95^{th} percentile queue length of 206.1 m, and an average travel speed of 26.9 kmph. The comparison of the performance index and 95^{th} percentile queue for each option is shown in **Figure 4-34**.

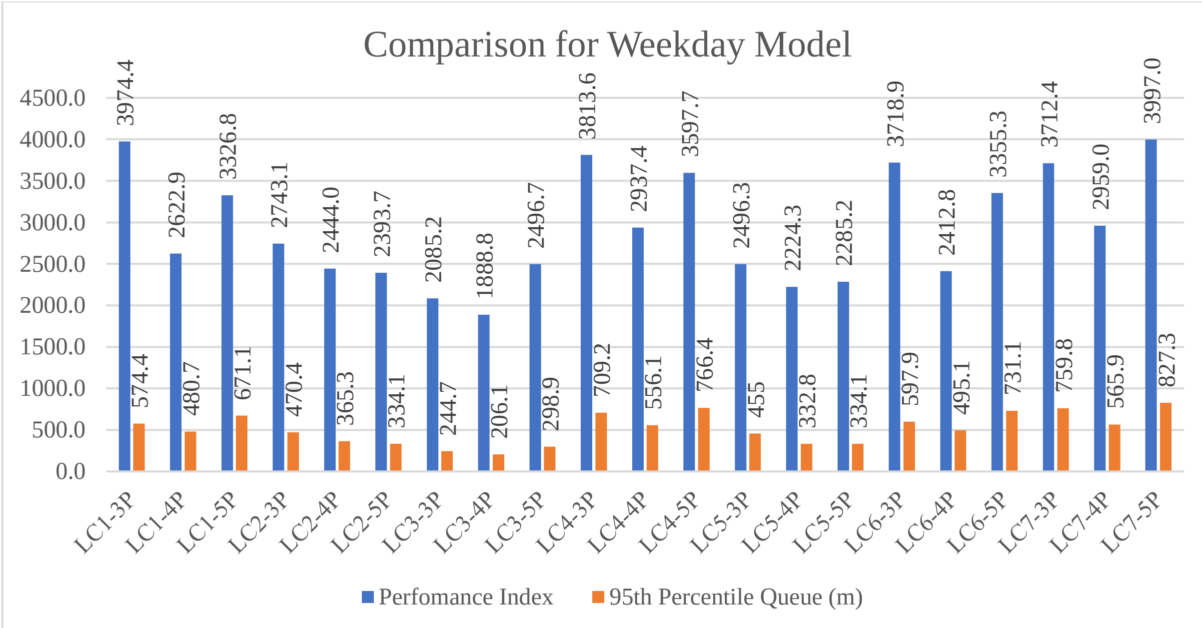


Figure 4-34: Comparison of Options for the Weekday Model

The phase time summary & the LoS summary of the same is shown and **Table 4-17** and **Figure 4-35** respectively.

Table 4-17: Phase time summary for LC3-4P Configuration

Phase	**A**	**B**	**C**	**D**
Change Time (sec)	0	21	33	63
Green Time (sec)	18	9	27	24
Phase Time (Sec)	21	12	30	27
Phase Split	23%	13%	33%	30%

	Approaches				Intersection
	South	East	North	West	
LOS	C	A	D	A	C

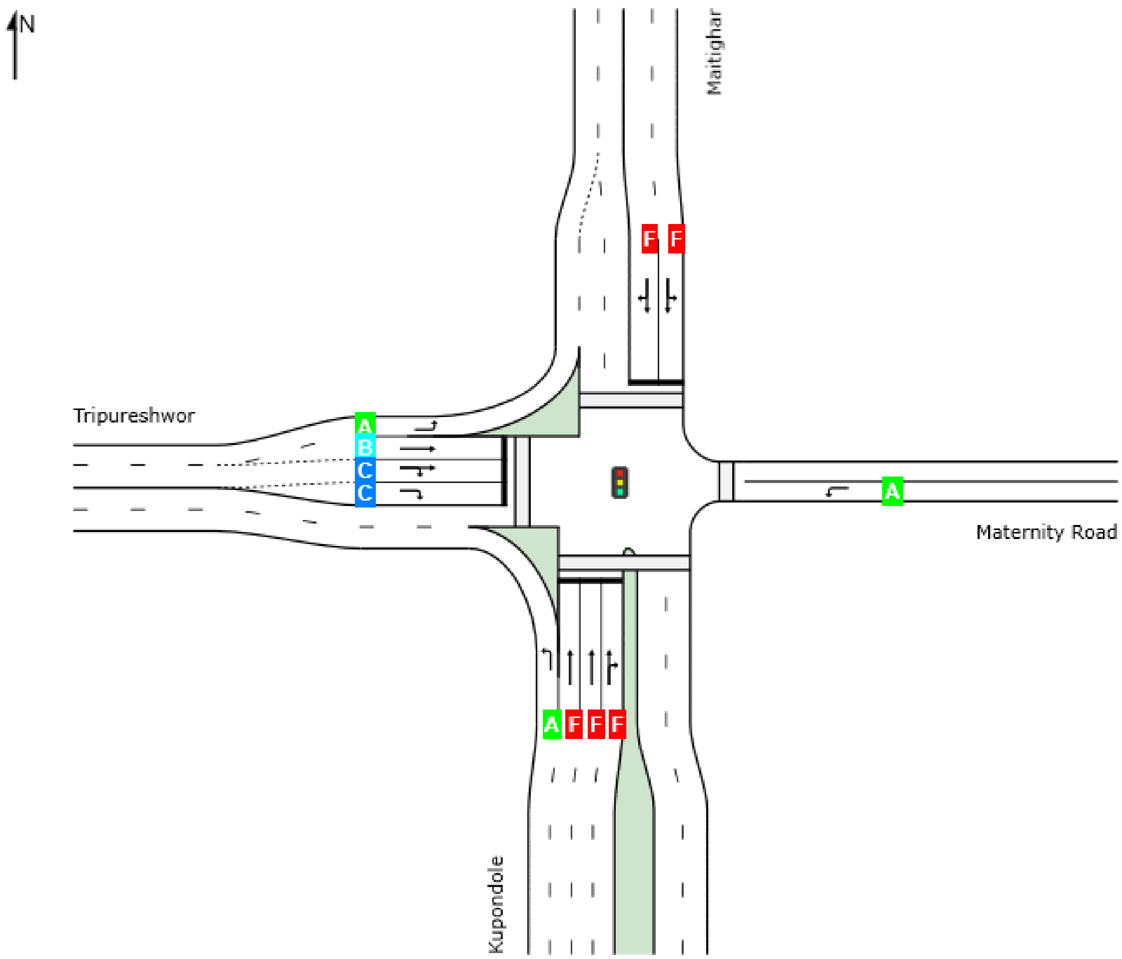


Figure 4-35: LoS Summary for Option LC3-4P

4.13 Evaluation of Intersection's performance under various Lane and Phase reconfiguration options for the weekend model

Similar to improvement options provided for the weekday model, options to improve the performance of the intersection during weekends following lane and phase reconfiguration options were analyzed.

4.13.1 Lane Configuration LC1 with Phase Reconfigurations

The lane configuration and phase reconfigurations provided for option LC1 are similar to option LC1 which is discussed in section **4.12.1**.

4.13.2 Lane Configuration LC2 with Phase Reconfigurations

The lane configuration and phase reconfigurations provided for option LC2 are similar to option LC2 which is discussed in section **4.12.2**.

4.13.3 Lane Configuration LC3 with Phase Reconfigurations

The lane configuration and phase reconfigurations provided for option LC3 are similar to option LC3 which is discussed in section **4.12.3**.

4.13.4 Lane Configuration LC4, LC5, LC6, LC7 with Phase Reconfigurations

The lane configuration and phase reconfigurations provided for options LC4 to LC7 are similar to options LC4 to LC7 which is discussed in section **4.12.4**.

4.13.5 Comparison of various Options for the weekend model

Various performance statistics were compared for all the options of the weekend model but based on the performance index the best option was selected.

Table 4-18: Comparing weekend model performance across options.

Option	Cycle Time	Performance Index	DoS	Average Delay	LoS	95% Back of Queue		Average Speed
						Vehicles	Distance	
	sec		v/c	sec		veh	m	km/h
LC1-3P	90	3174.7	1.243	81.2	F	153.2	417.2	18.7
LC1-4P	80	2079.6	1.175	44	D	127.8	348.1	23.3
LC1-5P	100	2205.7	1.175	43.4	D	150.8	410.7	23.2
LC2-3P	90	2160.9	1.193	55	E	131	370.8	21.8
LC2-4P	80	1824.4	1.107	43.4	D	90.4	256	23.2
LC2-5P	90	1552.6	0.927	24	C	73.9	208.7	26.9
LC3-3P	80	1605.4	0.884	21.2	C	68.8	187.4	27.5
LC3-4P	80	1394.4	0.845	18.1	B	50.9	136.9	28.1
LC3-5P	100	1493.1	0.809	18	B	53	149.3	28.2
LC4-3P	110	3386.8	1.446	111.9	F	214.9	585.3	16.1
LC4-4P	90	2308.7	1.227	60	E	153.2	417.2	21.1
LC4-5P	110	2439.3	1.249	58.3	E	178.4	485.9	21.1
LC5-3P	100	2018.0	1.086	46.9	D	121.2	343.1	22.9

Option	Cycle Time	Performance Index	DoS	Average Delay	LoS	95% Back of Queue		Average Speed
						Vehicles	Distance	
	sec		v/c	sec		veh	m	km/h
LC5-4P	90	1688.4	1.049	35.6	D	85.5	242	24.5
LC5-5P	80	1435.9	0.978	24.4	C	66.4	187.7	26.8
LC6-3P	100	3094.2	1.201	71.1	E	162	441.2	19.7
LC6-4P	90	1973.8	1.116	35.8	D	136.8	372.6	24.7
LC6-5P	110	2179.5	1.14	38.1	D	157.9	430	24.2
LC7-3P	110	3267.1	1.469	104	F	227.9	620.5	16.7
LC7-4P	100	2453.3	1.183	59.7	E	162	441.2	20.9
LC7-5P	130	2781.0	1.147	60.7	E	182.5	496.9	20.5

Option LC3-4P with the least performance index of 1394.4 is chosen as the best option for the weekend model. This option has a degree of saturation of 0.845, an average delay of 18.1 sec, LoS of B, 95th percentile queue length of 50.9 m, and an average travel speed of 28.1 kmph. The comparison of the performance index and 95th percentile queue for each option is shown in **Figure 4-36**.

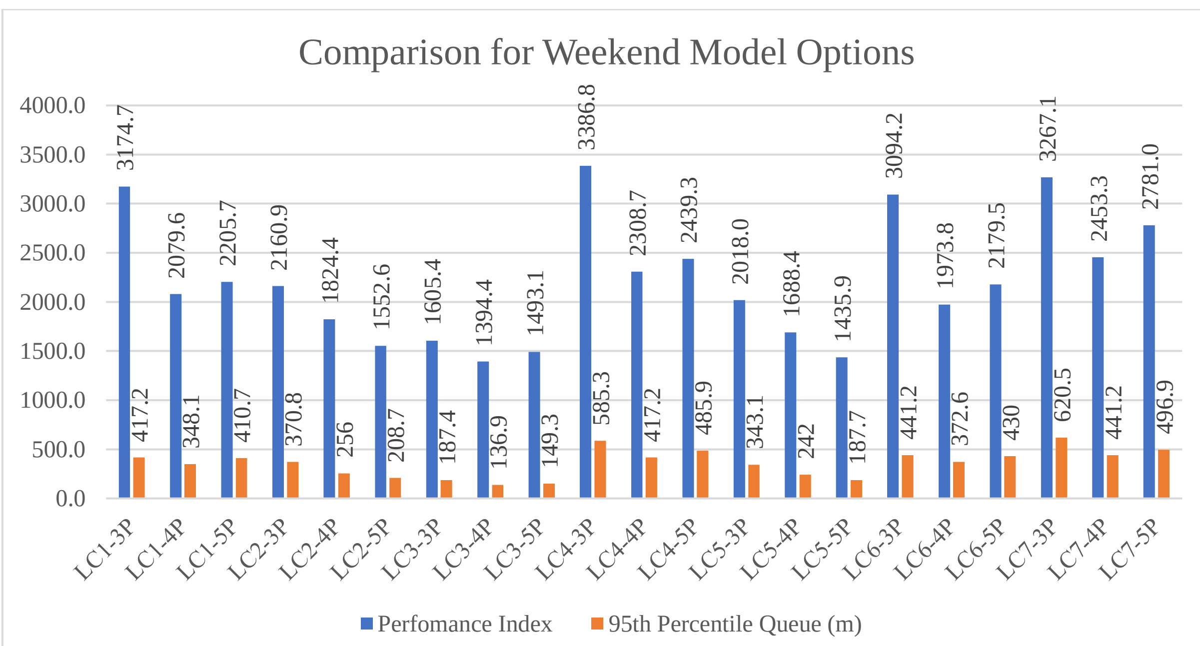


Figure 4-36: Comparison of Options for the Weekend Model

The phase time summary & the LoS summary of the same is shown **Table 4-19** & **Figure 4-37** respectively.

Table 4-19: Phase time summary for LC3-4P Configuration

Phase	A	B	C	D
Change Time (sec)	0	13	30	57
Green Time (sec)	10	14	24	20
Phase Time (Sec)	13	17	27	23
Phase Split	16%	21%	34%	29%

	Approaches				Intersection
	South	East	North	West	
LOS	B	A	C	B	B

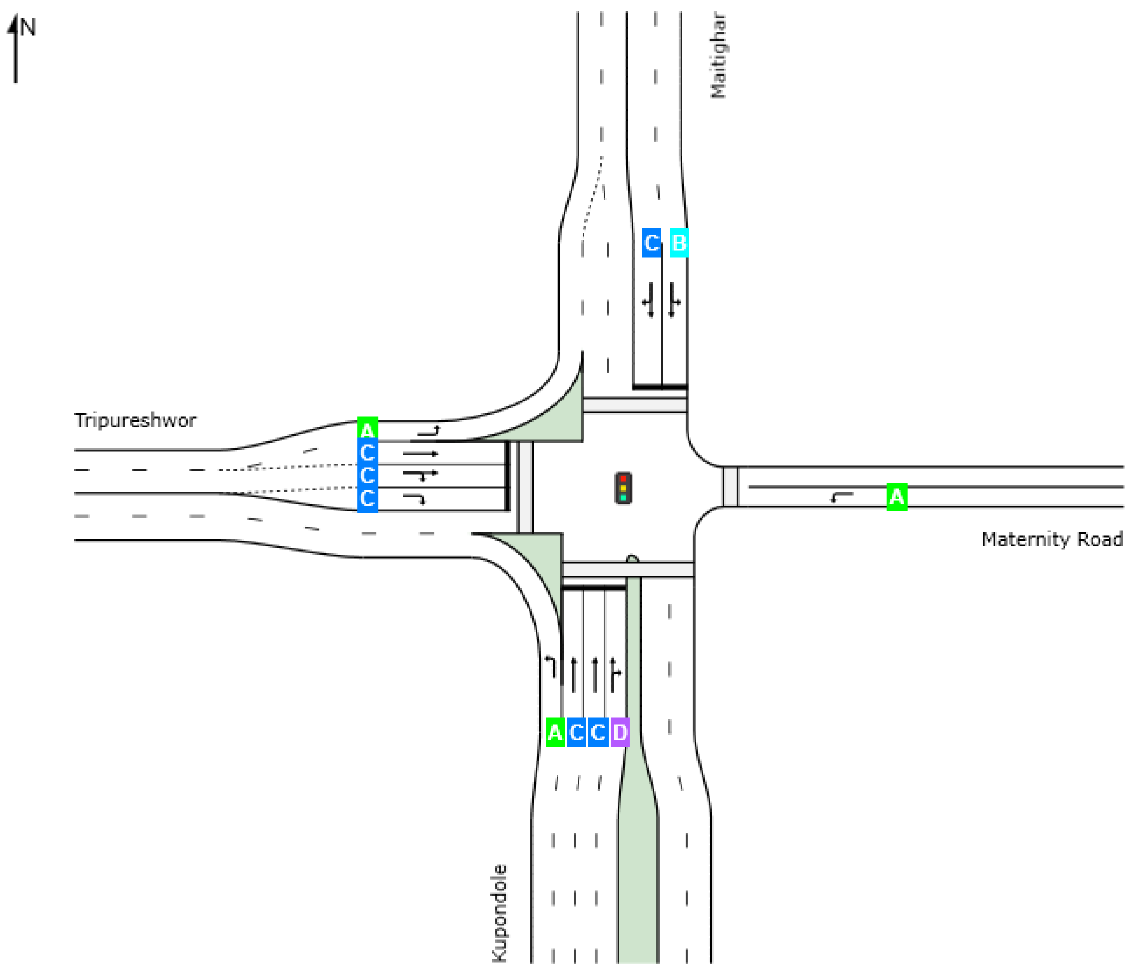


Figure 4-37: LoS Summary for Option LC3-4P

4.14 Evaluation of Intersection's Performance for the future years

For the proposed options for both weekday and weekend models, it was evaluated that the option LC3-2 and LC6-2 respectively performed the best for the base year 2022. Furthermore, these best options for the weekday and weekend models were analyzed for the future design period of 5, and 10 years resulting in years 2027, and 2032 respectively. The growth rate for each vehicle class was adopted from the KVITSP project (Department of Road, 2022) as shown in **Table 4-20**.

Table 4-20: Growth Rate of Vehicle Class

Vehicle Class	Growth Rate (%) (2026-2030)	Growth Rate (%) (2030-2035)
Light Vehicles (LV)	2.8	2.2
Heavy Vehicles (HV)	0	0
Buses (B)	0	0
Mini Buses (mB)	2.8	2.2
Micro Buses (uB)	3.6	2.8
Cars (C)	4.1	3.3
Jeeps (J)	3.7	3.0
Tempos (T)	0	0
Motor Cycles (MC)	5.6	4.5

4.14.1 Future Analysis for the Weekday Model

The future growth analysis for the weekday model under both PCU conditions showed similar trends. For the weekday model results were that by the year 2027, the intersection will perform with LoS E with DoS of 1.252, an average delay of 71.7 sec/veh, a 95th percentile queue length of 392.3 m, and an average travel speed of 19.4 kmph. But, after the year 2032, the intersection will perform at LoS F. The demand flows, degree of saturation, average delay, and 95th percentile queue all will increase. The summary of future growth analysis for the weekday model is shown in **Table 4-21**.

Table 4-21: Future growth analysis for the LC3-4P Weekday model

Year	Cycle Time	Performance Index	Demand Flows		DoS	Average Delay	LoS	95% Back of Queue		Average Speed
			Total	HV				Vehicles	Distance	
	sec		veh/h	%	v/c	sec		veh	m	km/h
2027	90	3727.3	16965	0.6	1.252	71.7	E	149	392.3	19.4
2032	90	4533.9	18405	0.5	1.350	91.8	F	183.8	480.6	17.5

4.14.2 Future Analysis for the Weekend Model

The future growth analysis for the weekend model results that by the year 2027, the intersection will perform with LoS E with DoS of 1.15, an average delay of 55.4 sec/veh, a 95th percentile queue length of 291.4 m, and an average travel speed of 21.4 kmph. After the year 2032, the intersection will perform at LoS E. The demand flows, degree of saturation, average delay, and 95th percentile queue all will increase compared to the LC3-4P Weekend model for the base year 2022. The summary of future growth analysis for the weekend model is shown in **Table 4-22**.

Table 4-22: Future growth analysis for the LC3-4P Weekend model

Year	Cycle Time	Performance Index	Demand Flows		DoS	Average Delay	LoS	95% Back of Queue		Average Speed
			Total	HV				Vehicles	Distance	
	sec		veh/h	%	v/c	sec		veh	m	km/h
2027	70	2783	13117	0.7	1.15	55.4	E	106.6	291.4	21.4
2032	70	3447.4	14182	0.6	1.224	74.4	E	132.5	361.6	19.2

4.15 Geometric Enhancements proposed for the Intersection for the year 2032

Based on the 2032 performance analysis of the intersection with best option selected for both weekday and weekend model, it was observed that the level of service (LoS) for weekday model is rated as “F” while for weekend model is rated as "E" due to the annual increase in traffic volume. The Thapathali intersection after 2027 will face operational challenges due to limited Right of Way (ROW). Options considered for addressing this limitation include the implementation of a flyover, underpass, or a combination of both. Based on the flow reduction calculation with 3 comparative modeling it shows that the flyover is the most technically efficient (Mudiono, 2015). Consequently, a geometric enhancement for the Thapathali intersection incorporating a flyover has been adopted. The geometric improvement can be the addition of two-lane flyover from Maitighar leg to Tripureshwor leg along with a pedestrian underpass. The proposed geometric enhancement for the Thapathali intersection for 2032 onwards is depicted in **Figure 4-38**.

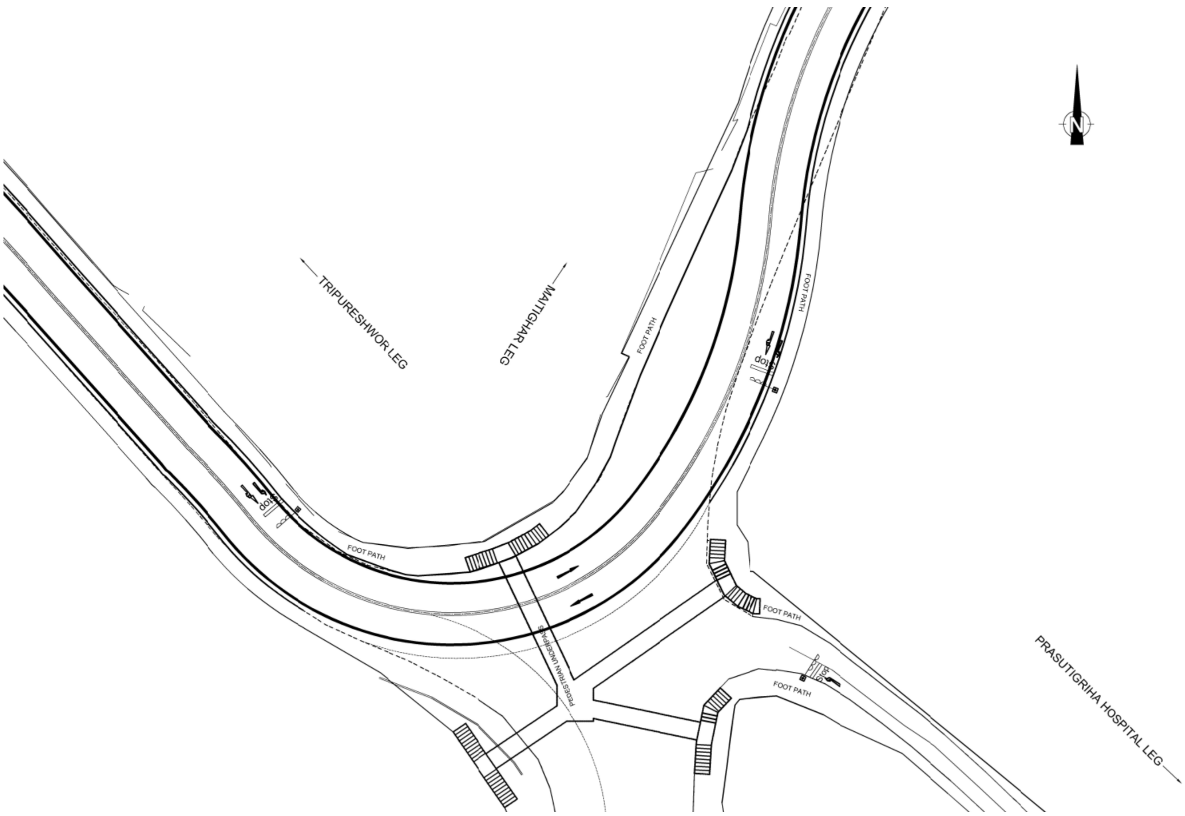


Figure 4-38: Proposed geometric enhancement of the Intersection

The proposed enhancement for the intersection involves the addition of a double lane flyover placed over a girder of height 4 m which is again placed over a central pier of height 5m and width 3m along the centerline of Maitighar leg to Tripureshwor leg. This configuration separates the right turn movement from Maitighar to Tripureshwor and the left turn movement from Tripureshwor to Maitighar rendering a smaller number of conflicts. In order to avoid pedestrian conflicts a 4-way pedestrian underpass is also proposed. Other all traffic movement remains the same as in LC3-4P configuration.

4.15.1 Evaluation of performance of the Intersection with proposed geometric enhancements during weekdays

This proposed model for the weekdays with proposed geometric enhancements has a phase reconfiguration with 5 phase plans which is shown in **Figure 4-39**.

Figure 4-39: Phase plan for the weekday model with geometric enhancements

After processing the model in SIDRA with optimum cycle timing option, it was observed that the intersection will operate under LoS B and PI of 1495.6 with DoS of 1.026, average delay of 17.7 sec/veh, 218.7 m of 95th percentile BoQ and average travel speed of 26.7 kmph. The summary of LoS for the intersection in shown in **Figure 4-40**. The assessment of LoS for approaches and the intersection in SIDRA Intersection exclusively relies on the average delay value, thereby overlooking instances where the DoS exceeds 1 (Akcelik & Associates Pty Ltd, 2018).

	Approaches				Intersection
	South	East	North	West	
LOS	B	A	A	D	B

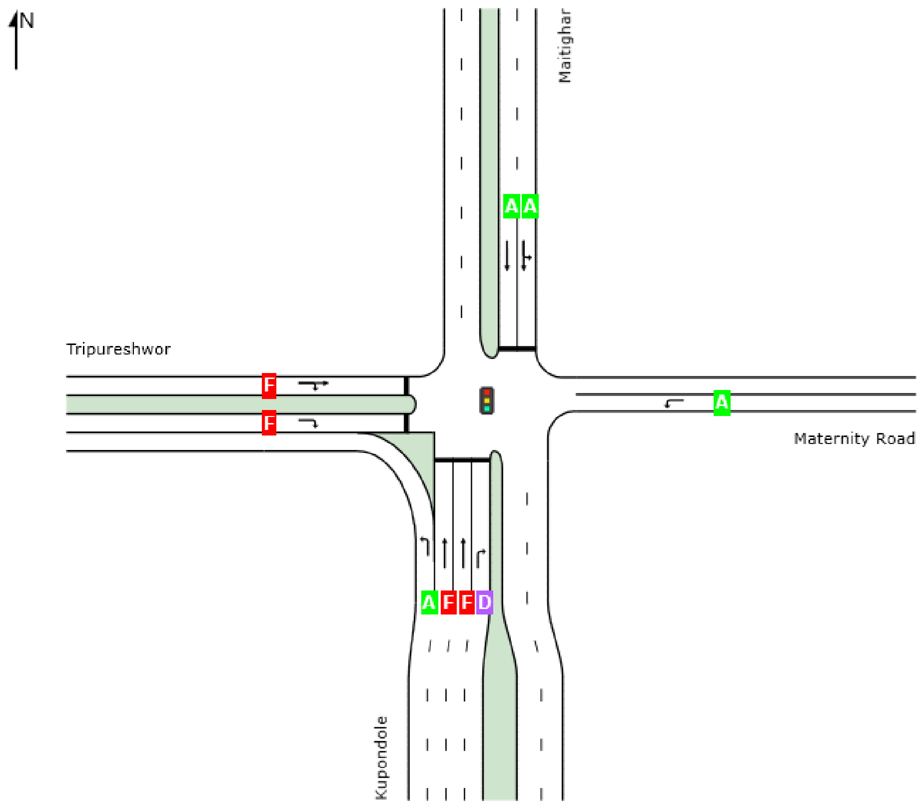


Figure 4-40: LoS Summary for proposed geometric enhancements during weekdays

The summary of the phase timing and performance statistics are show in **Table 4-23** and **Table 4-24** respectively.

Table 4-23: Phase timing summary for the weekday model with geometric enhancements

Phase	A	B	C	D	E
Change Time (sec)	0	11	20	62	71
Green Time (sec)	8	6	39	6	26
Phase Time (sec)	11	9	42	9	29
Phase Split	11%	9%	42%	9%	29%

Table 4-24: Performance Statistics for the weekday model with geometric enhancements

Turn	Demand Flows		DoS	Average Delay	LoS	95% Back of Queue		Average Speed
	Total	HV				Vehicles	Distance	
	veh/h	%	v/c	sec		veh	m	km/h
South: Kupondole								
L2	3957	0.4	0.816	0.2	A	0	0	33.4
T1	3782	0.5	1.026	36.1	F	83.4	218.7	22.3
R2	524	0	0.873	39.6	D	21	53.4	22.9
Approach	8264	0.4	1.026	19.1	B	83.4	218.7	26.7
East: Maternity Road								
L2	925	0	0.231	0	A	0	0	28.5
Approach	925	0	0.231	0	A	0	0	28.5
North: Maitighar								
L2	333	0	0.555	5.2	A	28.3	74.2	29
T1	2643	0.2	0.555	5.3	A	29.2	76.3	28.9
Approach	2976	0.2	0.555	5.3	A	29.2	76.3	28.9
West: Tripureshwor								
T1	403	0	1.008	66.1	F	22.6	53.7	17.3
R2	1145	1	1.008	37.2	F	53.4	139.6	24.7
Approach	1548	0.7	1.008	44.7	D	53.4	139.6	22.6
All Vehicles	13713	0.4	1.026	17.7	B	83.4	218.7	26.7

4.15.2 Evaluation of performance of the Intersection with proposed geometric enhancements during weekends

The model with proposed geometric enhancements for weekends is similar to that for weekdays. After processing the model in SIDRA with optimum cycle timing option, it was observed that the intersection will operate under LoS B and PI of 1203.2 with DoS of 1.017, average delay of 16.6 sec/veh, 176.6 m of 95th percentile BoQ and average travel speed of 27.3 kmph. As SIDRA Intersection only considers the average delay value for determining LoS for approaches and the intersection, the DoS being greater than 1 is overlooked (Akcelik & Associates Pty Ltd, 2018). The summary of LoS for the intersection in shown in **Figure 4-41**.

	Approaches				Intersection
	South	East	North	West	
LOS	B	A	A	C	B

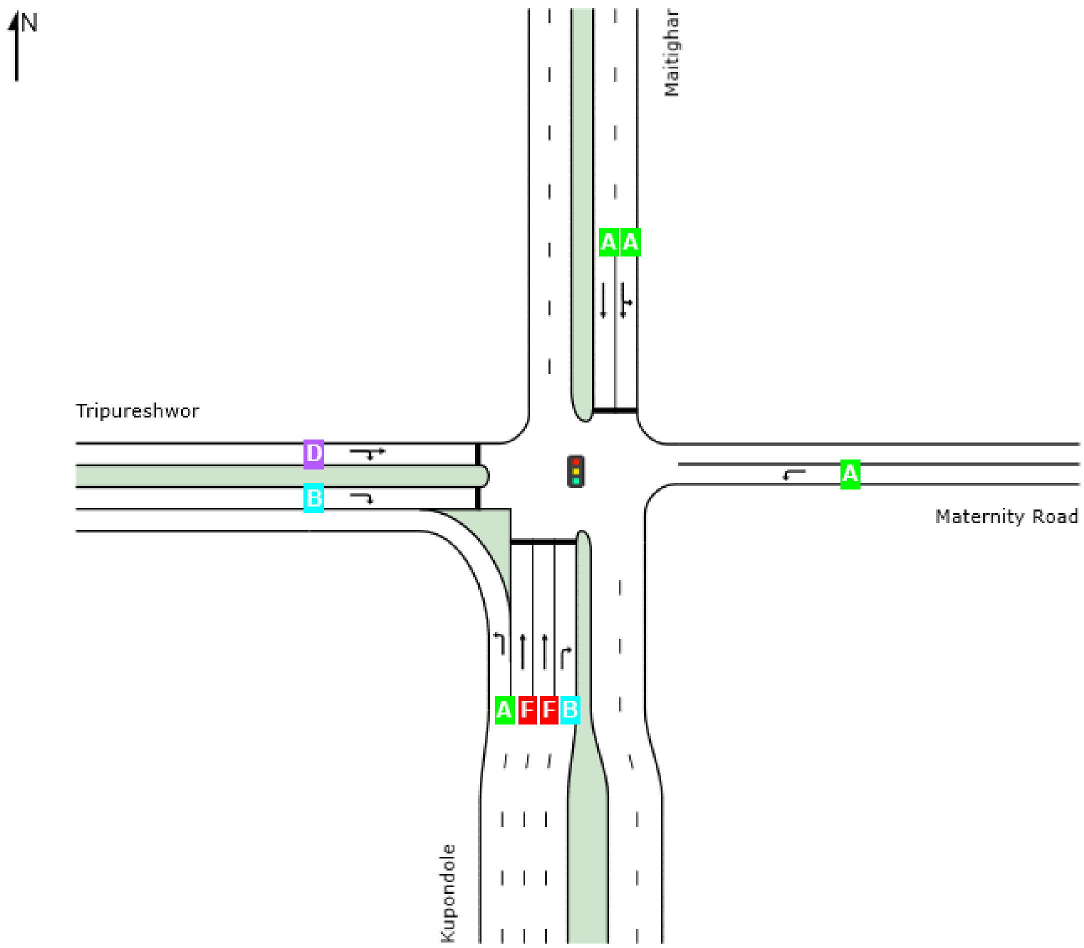


Figure 4-41: LoS Summary for proposed geometric enhancements during weekends

The summary of the phase timing and performance statistics are show in **Table 4-25** and **Table 4-26** respectively.

Table 4-25: Phase timing summary for the weekend model with geometric enhancements

Phase	A	B	C	D	E
Change Time (sec)	0	12	21	50	59
Green Time (sec)	9	6	26	6	23
Phase Time (sec)	12	9	29	9	26
Phase Split	14%	11%	34%	11%	31%

Table 4-26: Performance Statistics for the weekend model with geometric enhancements

Turn	Demand Flows		DoS	Average Delay	LoS	95% Back of Queue		Average Speed
	Total	HV				Vehicles	Distance	
	veh/h	%	v/c	sec		veh	m	km/h
South: Kupondole								
L2	2576	0.5	0.601	0.1	A	0	0	33.5
T1	3306	0.7	1.017	35.9	F	67.3	176.6	22.7
R2	328	0	0.413	16.3	B	7.6	19.3	27.7
Approach	6209	0.6	1.017	20	B	67.3	176.6	26.5
East: Maternity Road								
L2	370	0	0.084	0	A	0	0	28.5
Approach	370	0	0.084	0	A	0	0	28.5
North: Maitighar								
L2	209	0	0.578	6.3	A	25.1	68	28.7
T1	2382	0.4	0.578	6.5	A	25.1	68	28.7
Approach	2591	0.4	0.578	6.5	A	25.1	68.5	28.7
West: Tripureshwor								
L2	393	0	0.912	40.6	D	15.8	38.4	23.8
T1	1088	0.8	0.912	18.4	B	30.2	81.9	29.7
Approach	1481	0.6	0.912	24.3	C	30.2	81.9	28.1
All Vehicles	10651	0.5	1.017	16.6	B	67.3	176.6	27.3

Chapter 5: CONCLUSION AND RECOMMENDATION

This research study aimed to perform analysis of operational performance of the Thapathali intersection during weekdays and weekends and to propose viable alternatives to enhance the performance of the intersection at present condition and in future period of time.

5.1 Conclusion

i. The initial traffic volume analysis indicated the peak hour volume during weekdays was 5598 PCU in the morning and 4886 PCU in the evening, while the weekend traffic volume was 4697 PCU in the morning and 4597 PCU in the evening.

ii. On an average for the 5 days, motorcycles and cars / taxis constituted highest and second highest traffic with 70.58% and 17.92% of traffic mix respectively.

iii. The initial performance evaluation of the intersection demonstrated that during weekdays the intersection was performing at LoS F with degree of saturation of 2.215, average delay of 99.6 sec/veh, and average travel speed of 16.6 kmph. While during weekends, the intersection was performing at LoS D with degree of saturation of 1.353, average delay of 35.1 sec/veh, and average travel speed of 24.7 kmph.

iv. Out of 7 options proposed for the weekday model, the LC3-4P model (Tripureshwor Leg's Lane reconfiguration with 4 phase timing plan) with a performance index of 1888.8, LoS C, degree of saturation of 0.978, average delay of 24.1 sec/veh, and average travel speed of 26.9 kmph is the best option.

v. Out of 7 options proposed for the weekend model, the LC3-4P model (Tripureshwor Leg's Lane reconfiguration with 4 phase timing plan) with a performance index of 1394.4, LoS B, degree of saturation of 0.845, average delay of 18.1 sec/veh, and average travel speed of 28.1 kmph is the best option.

vi. On analysis of the performance of the intersection for future design period of 5 and 10 years, it was revealed that intersection during weekdays will operate under LoS E till 2027 and during weekends it will operate under LoS E till 2032.

vii. With geometric enhancements of addition of two-lane flyover from Maitighar Leg to Tripureshwor Leg along with pedestrian underpass with 5 phase configurations, the performance of the intersection will be enhanced. In the analysis of the intersection during 2032 with proposed geometric enhancements it was observed that during weekdays the intersection will have improved performance with LoS B, degree of saturation of 1.026, and average delay of 17.7 sec/veh while during weekends the intersection will have improved performance with LoS B, degree of saturation of 1.017, and average delay of 16.6 sec/veh.

5.2 Recommendation

The following points are recommended:

- Considerable research effort was invested in conducting 16-hour traffic flow counts over a 5-day period. To save time and enhance efficiency, the deployment of a machine learning-powered software solution could be used to automate the traffic counting process.
- The current analysis of the intersection was performed in isolation and did not consider the impact of neighboring intersections. The study of (Tiwari, Luitel, & Pokhrel, 2023) could referred to optimize intersection's performance through signal coordination. To enhance the accuracy and comprehensiveness of future research, it is recommended to conduct a network-level analysis that incorporates the Maitighar Intersection, the Thapathali Intersection, and the Tripureshwor Intersection.
- The current intersection model was developed using saturation flow values obtained from the Indo-HCM equations. To improve the model's accuracy, a separate saturation flow study could be conducted at the intersection.
- The model calibration and validation process currently rely solely on the 95^{th} percentile back of queue as a variable measure. To enhance the model's accuracy, saturation flow and degree of saturation could be used as additional variables for calibration and validation.
- To take advantage of the latest advancements in technology and methods, a more recent version of SIDRA 9.1 could be used to perform the study, allowing for comparison with previous versions. To evaluate the performance and capabilities of different traffic analysis software, a similar research study could be conducted in a comparative manner, including popular software such as VISSIM, SimTraffic, CORSIM, and others.

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APPENDICES: SUMMARY OF DATA

Appendix A: 15 minutes classified vehicle counts

Appendix A.1: 15 minutes classified vehicle counts for Day-1

Start Time	End Time	Multi Axle Truck	Heavy Truck	Light Truck	Standard Bus	Mini Bus	Micro Bus	Car / Taxi	Utility Vehicle	Four Wheel Drive	Motorized Three-Wheeler	Motor Cycle	Total
6:00:00	6:15:00	-	4	4	26	5	42	87	31	27	24	658	908
6:15:00	6:30:00	-	4	2	43	6	50	117	41	24	20	762	1,069
6:30:00	6:45:00	-	5	2	46	10	59	107	49	33	29	830	1,170
6:45:00	7:00:00	-	4	1	48	5	50	126	44	46	30	985	1,339
7:00:00	7:15:00	-	3	-	43	10	69	138	45	40	28	861	1,237
7:15:00	7:30:00	-	4	-	74	8	64	157	48	69	24	709	1,157
7:30:00	7:45:00	-	1	-	53	11	64	170	50	79	20	750	1,198
7:45:00	8:00:00	-	4	1	72	7	64	193	53	90	25	950	1,459
8:00:00	8:15:00	-	1	2	59	9	57	253	62	134	21	997	1,595
8:15:00	8:30:00	1	2	-	56	7	63	266	52	160	26	1,064	1,697
8:30:00	8:45:00	-	4	1	47	7	67	323	52	158	27	1,205	1,891
8:45:00	9:00:00	-	2	2	41	6	45	357	43	201	26	1,503	2,226
9:00:00	9:15:00	-	1	1	43	6	44	401	41	215	31	1,966	2,749
9:15:00	9:30:00	-	2	-	25	6	53	350	24	205	26	2,184	2,875
9:30:00	9:45:00	-	-	1	32	2	38	359	36	219	37	2,126	2,850
9:45:00	10:00:00	-	3	1	35	9	58	367	29	197	45	2,462	3,206
10:00:00	10:15:00	-	-	-	32	5	52	352	28	206	30	2,192	2,897
10:15:00	10:30:00	-	2	-	36	5	46	370	29	178	35	1,995	2,696
10:30:00	10:45:00	-	3	-	45	4	58	371	22	181	32	2,006	2,722
10:45:00	11:00:00	-	2	3	40	4	63	335	29	172	37	1,915	2,600
11:00:00	11:15:00	-	1	-	36	4	62	323	64	153	33	1,926	2,602

Start Time	End Time	Multi Axle Truck	Heavy Truck	Light Truck	Standard Bus	Mini Bus	Micro Bus	Car / Taxi	Utility Vehicle	Four Wheel Drive	Motorized Three-Wheeler	Motor Cycle	Total
11:15:00	11:30:00	-	-	4	28	3	55	343	42	149	33	1,819	2,476
11:30:00	11:45:00	-	1	-	33	4	52	332	75	135	30	1,855	2,517
11:45:00	12:00:00	-	3	1	28	3	79	319	65	145	28	1,841	2,512
12:00:00	12:15:00	-	2	2	30	7	71	352	66	154	28	1,978	2,690
12:15:00	12:30:00	-	1	-	26	3	62	333	66	161	24	1,793	2,469
12:30:00	12:45:00	-	2	2	27	5	70	320	68	169	23	1,960	2,646
12:45:00	13:00:00	-	1	-	28	1	70	310	43	172	25	1,932	2,582
13:00:00	13:15:00	-	2	1	33	1	57	345	67	171	26	1,810	2,513
13:15:00	13:30:00	-	1	-	32	4	46	350	62	182	29	1,976	2,682
13:30:00	13:45:00	-	2	2	24	4	76	310	53	160	23	1,805	2,459
13:45:00	14:00:00	-	2	-	33	4	51	303	51	167	25	1,719	2,355
14:00:00	14:15:00	-	1	-	31	3	63	298	62	167	27	1,624	2,276
14:15:00	14:30:00	-	5	-	32	5	81	333	66	168	28	1,650	2,368
14:30:00	14:45:00	-	9	1	47	3	92	314	59	196	32	1,706	2,459
14:45:00	15:00:00	-	4	1	35	3	65	341	68	190	24	1,707	2,438
15:00:00	15:15:00	-	2	-	40	1	77	341	61	184	30	1,740	2,476
15:15:00	15:30:00	-	4	2	40	3	81	325	67	175	32	1,754	2,483
15:30:00	15:45:00	-	2	2	56	4	74	317	54	187	27	1,620	2,343
15:45:00	16:00:00	1	1	-	42	2	65	306	61	181	29	1,728	2,416
16:00:00	16:15:00	-	2	-	55	5	61	338	36	168	23	1,735	2,423
16:15:00	16:30:00	-	1	1	38	6	58	318	29	186	28	1,784	2,449
16:30:00	16:45:00	-	-	-	47	4	59	328	26	164	31	1,831	2,490
16:45:00	17:00:00	-	1	2	37	4	66	353	39	174	29	1,762	2,467
17:00:00	17:15:00	1	1	-	47	3	60	363	24	169	26	1,815	2,509
17:15:00	17:30:00	-	2	-	44	2	55	323	27	169	26	1,835	2,483
17:30:00	17:45:00	-	-	-	37	2	51	302	32	183	21	1,395	2,023
17:45:00	18:00:00	-	2	-	31	7	54	346	27	178	20	1,904	2,569
18:00:00	18:15:00	-	-	-	29	1	52	343	23	166	18	1,918	2,550
18:15:00	18:30:00	-	1	-	41	2	39	370	26	171	17	1,753	2,420
18:30:00	18:45:00	-	-	-	28	3	54	359	31	198	21	1,675	2,369
18:45:00	19:00:00	-	1	-	40	6	55	351	33	184	10	1,574	2,254
19:00:00	19:15:00	-	-	1	36	3	61	315	49	165	16	1,545	2,191

Start Time	End Time	Multi Axle Truck	Heavy Truck	Light Truck	Standard Bus	Mini Bus	Micro Bus	Car / Taxi	Utility Vehicle	Four Wheel Drive	Motorized Three-Wheeler	Motor Cycle	Total
19:15:00	19:30:00	-	1	1	18	2	39	295	35	119	12	1,382	1,904
19:30:00	19:45:00	-	3	1	15	-	43	323	25	116	5	1,459	1,990
19:45:00	20:00:00	-	2	-	12	1	31	297	44	92	2	1,228	1,709
20:00:00	20:15:00	4	1	20	11	-	40	287	41	88	4	980	1,476
20:15:00	20:30:00	-	4	13	3	-	21	258	34	89	2	852	1,276
20:30:00	20:45:00	2	3	19	3	-	19	237	21	73	-	747	1,124
20:45:00	21:00:00	5	-	10	7	-	19	250	26	61	1	634	1,013
21:00:00	21:15:00	1	12	16	1	-	21	224	23	54	-	532	884
21:15:00	21:30:00	-	10	12	2	-	17	184	22	55	-	457	759
21:30:00	21:45:00	1	11	8	-	-	7	158	21	53	-	451	710
21:45:00	22:00:00	-	15	12	-	-	16	144	16	46	-	297	546
22:00:00	22:15:00	-	9	4	-	-	3	70	9	15	-	135	245
Total		**16**	**179**	**159**	**2,159**	**250**	**3,456**	**18,850**	**2,747**	**9,136**	**1,441**	**95,743**	**134,136**

Appendix A.2: 15 minutes classified vehicle counts for Day-2.

Start Time	End Time	Multi Axle Truck	Heavy Truck	Light Truck	Standard Bus	Mini Bus	Micro Bus	Car / Taxi	Utility Vehicle	Four Wheel Drive	Motorized Three-Wheeler	Motor Cycle	Total
6:00:00	6:15:00	-	-	3	18	3	37	68	23	14	22	500	688
6:15:00	6:30:00	-	3	9	24	8	43	132	30	32	24	811	1,116
6:30:00	6:45:00	-	1	5	35	6	60	113	40	26	27	795	1,108
6:45:00	7:00:00	-	1	3	35	11	51	130	30	31	29	959	1,280
7:00:00	7:15:00	-	2	3	29	11	54	120	37	32	31	847	1,166
7:15:00	7:30:00	-	2	1	45	22	69	191	38	45	23	697	1,133
7:30:00	7:45:00	-	1	4	40	13	60	220	40	45	25	820	1,268
7:45:00	8:00:00	1	4	1	59	16	58	211	25	75	25	974	1,449
8:00:00	8:15:00	-	2	2	52	17	49	250	34	108	31	1,003	1,548
8:15:00	8:30:00	-	-	3	44	10	67	328	44	99	23	1,049	1,667
8:30:00	8:45:00	-	1	2	34	15	75	377	43	89	26	1,311	1,973
8:45:00	9:00:00	-	2	-	36	10	58	489	26	120	33	1,911	2,685
9:00:00	9:15:00	-	1	1	29	18	56	528	21	116	31	2,474	3,275
9:15:00	9:30:00	-	-	1	26	13	42	474	13	160	26	2,586	3,341
9:30:00	9:45:00	-	1	2	27	13	46	404	14	151	36	2,607	3,301
9:45:00	10:00:00	-	1	3	40	16	41	468	12	128	33	2,494	3,236
10:00:00	10:15:00	-	-	1	32	5	55	487	7	103	44	2,301	3,035
10:15:00	10:30:00	-	-	1	24	12	40	442	12	89	35	1,959	2,614
10:30:00	10:45:00	-	1	4	26	9	52	467	7	100	41	2,021	2,728
10:45:00	11:00:00	-	1	-	32	10	54	481	24	95	39	1,995	2,731
11:00:00	11:15:00	-	1	1	25	8	46	418	33	117	28	1,770	2,447
11:15:00	11:30:00	-	-	2	22	9	48	472	46	106	42	1,907	2,654
11:30:00	11:45:00	-	1	2	23	13	54	447	41	71	31	1,973	2,656
11:45:00	12:00:00	-	-	-	15	15	66	391	40	93	37	2,024	2,681
12:00:00	12:15:00	-	1	1	25	6	53	409	46	128	26	2,049	2,744
12:15:00	12:30:00	-	-	4	23	8	58	447	45	95	34	1,976	2,690
12:30:00	12:45:00	-	-	3	24	16	67	406	49	118	27	2,101	2,811
12:45:00	13:00:00	-	-	1	29	15	53	415	52	118	35	1,980	2,698
13:00:00	13:15:00	-	2	2	17	11	56	426	45	75	25	1,707	2,366

Start Time	End Time	Multi Axle Truck	Heavy Truck	Light Truck	Standard Bus	Mini Bus	Micro Bus	Car / Taxi	Utility Vehicle	Four Wheel Drive	Motorized Three-Wheeler	Motor Cycle	Total
13:15:00	13:30:00	-	-	1	31	13	54	375	47	88	19	1,707	2,335
13:30:00	13:45:00	-	2	2	18	5	57	421	43	92	29	1,668	2,337
13:45:00	14:00:00	-	-	2	25	13	44	361	44	83	28	1,661	2,261
14:00:00	14:15:00	-	-	-	23	3	45	367	41	79	28	1,569	2,155
14:15:00	14:30:00	-	2	1	27	8	56	365	31	89	16	1,431	2,026
14:30:00	14:45:00	-	-	1	30	9	52	341	34	79	18	1,250	1,814
14:45:00	15:00:00	-	-	1	18	8	49	347	39	94	19	1,227	1,802
15:00:00	15:15:00	1	-	-	30	2	47	297	21	84	20	1,346	1,848
15:15:00	15:30:00	-	-	-	35	7	47	332	29	84	15	1,326	1,875
15:30:00	15:45:00	-	-	1	32	6	48	316	27	115	18	1,300	1,863
15:45:00	16:00:00	-	1	-	36	3	35	303	14	90	17	1,229	1,728
16:00:00	16:15:00	-	-	-	38	5	52	320	10	95	21	1,394	1,935
16:15:00	16:30:00	-	-	2	30	9	38	310	8	79	25	1,414	1,915
16:30:00	16:45:00	-	1	-	31	6	44	319	9	74	20	1,270	1,774
16:45:00	17:00:00	-	1	-	27	4	44	314	7	87	14	1,236	1,734
17:00:00	17:15:00	-	-	1	44	11	68	378	15	114	26	1,726	2,383
17:15:00	17:30:00	1	-	-	28	11	58	413	12	117	30	1,934	2,604
17:30:00	17:45:00	-	1	1	30	13	35	450	16	114	25	2,041	2,726
17:45:00	18:00:00	-	1	3	29	8	36	440	9	126	27	2,252	2,931
18:00:00	18:15:00	-	-	-	25	8	25	383	8	106	14	1,778	2,347
18:15:00	18:30:00	-	-	-	20	8	41	330	5	83	14	1,566	2,067
18:30:00	18:45:00	-	-	-	32	6	36	396	11	88	12	1,545	2,126
18:45:00	19:00:00	-	-	-	20	7	24	324	23	73	8	1,281	1,760
19:00:00	19:15:00	-	-	-	16	5	25	280	24	64	10	1,042	1,466
19:15:00	19:30:00	1	-	-	16	5	31	258	28	62	3	1,193	1,597
19:30:00	19:45:00	-	-	-	13	3	20	256	26	61	1	1,021	1,401
19:45:00	20:00:00	-	-	1	16	6	24	285	21	60	1	984	1,398
20:00:00	20:15:00	1	-	9	2	1	24	276	14	38	1	800	1,166
20:15:00	20:30:00	1	-	8	4	2	15	224	16	39	-	721	1,030
20:30:00	20:45:00	-	-	11	7	2	12	197	15	24	-	559	827
20:45:00	21:00:00	2	-	4	1	-	14	181	16	28	-	486	732
21:00:00	21:15:00	2	12	8	3	1	4	205	19	21	-	457	732

Start Time	End Time	Multi Axle Truck	Heavy Truck	Light Truck	Standard Bus	Mini Bus	Micro Bus	Car / Taxi	Utility Vehicle	Four Wheel Drive	Motorized Three-Wheeler	Motor Cycle	Total
21:15:00	21:30:00	2	7	5	3	-	8	175	17	29	-	376	622
21:30:00	21:45:00	-	14	6	-	2	4	148	15	21	-	323	533
21:45:00	22:00:00	-	4	3	1	1	4	145	14	27	-	256	455
22:00:00	22:15:00	-	1	-	-	-	2	27	1	7	-	71	109
Total		**12**	**76**	**136**	**1,631**	**540**	**2,790**	**21,070**	**1,646**	**5,193**	**1,368**	**91,041**	**125,503**

Appendix A.3: 15 minutes classified vehicle counts for Day-3

Start Time	End Time	Multi Axle Truck	Heavy Truck	Light Truck	Standard Bus	Mini Bus	Micro Bus	Car / Taxi	Utility Vehicle	Four Wheel Drive	Motorized Three-Wheeler	Motor Cycle	Total
5:45:00	6:00:00	-	-	2	1	5	11	46	15	4	7	204	295
6:00:00	6:15:00	-	2	8	5	16	41	109	41	10	16	534	782
6:15:00	6:30:00	-	-	10	2	29	49	126	40	22	21	676	975
6:30:00	6:45:00	-	-	7	5	35	39	110	45	23	23	788	1,075
6:45:00	7:00:00	-	-	4	8	48	44	167	49	18	24	950	1,312
7:00:00	7:15:00	-	-	6	6	46	58	166	43	39	21	949	1,334
7:15:00	7:30:00	-	-	7	9	35	50	233	40	40	23	908	1,345
7:30:00	7:45:00	-	-	3	5	44	50	269	39	49	28	1,011	1,498
7:45:00	8:00:00	-	-	3	12	51	50	278	44	45	30	1,019	1,532
8:00:00	8:15:00	-	-	9	6	46	46	326	52	54	19	968	1,526
8:15:00	8:30:00	-	-	12	10	47	50	362	60	79	28	1,106	1,754
8:30:00	8:45:00	-	-	9	12	30	43	417	55	56	32	1,235	1,889
8:45:00	9:00:00	-	-	5	10	31	51	439	54	60	30	1,769	2,449
9:00:00	9:15:00	-	-	4	7	26	40	486	27	63	24	1,985	2,662
9:15:00	9:30:00	-	-	3	9	28	37	442	26	59	34	2,048	2,686
9:30:00	9:45:00	-	-	1	4	25	38	483	27	62	31	2,153	2,824
9:45:00	10:00:00	-	-	2	6	30	41	466	15	69	40	2,142	2,811
10:00:00	10:15:00	-	-	2	8	34	53	485	20	85	43	2,330	3,060
10:15:00	10:30:00	-	-	6	7	39	45	534	33	91	40	2,296	3,091
10:30:00	10:45:00	-	-	-	4	42	53	492	23	90	38	2,063	2,805
10:45:00	11:00:00	-	-	7	5	39	43	434	34	96	41	1,891	2,590
11:00:00	11:15:00	-	-	23	6	33	41	475	50	74	22	1,768	2,492
11:15:00	11:30:00	-	-	15	6	30	48	478	49	74	36	2,237	2,973
11:30:00	11:45:00	-	-	17	3	34	44	450	57	81	35	2,154	2,875
11:45:00	12:00:00	-	-	21	8	30	43	509	57	105	32	2,018	2,823
12:00:00	12:15:00	-	-	17	3	18	48	369	63	107	18	2,305	2,948
12:15:00	12:30:00	-	-	21	11	34	49	425	58	101	25	2,446	3,170
12:30:00	12:45:00	-	-	24	12	31	71	460	62	86	27	1,279	2,052
12:45:00	13:00:00	-	-	19	6	24	58	544	69	106	29	1,377	2,232

Start Time	End Time	Multi Axle Truck	Heavy Truck	Light Truck	Standard Bus	Mini Bus	Micro Bus	Car / Taxi	Utility Vehicle	Four Wheel Drive	Motorized Three-Wheeler	Motor Cycle	Total
13:00:00	13:15:00	-	-	26	7	34	63	553	95	84	27	1,622	2,511
13:15:00	13:30:00	-	-	11	8	26	42	482	49	58	25	1,685	2,386
13:30:00	13:45:00	-	-	22	9	25	48	485	83	67	14	2,261	3,014
13:45:00	14:00:00	-	-	20	4	29	39	469	63	80	21	2,066	2,791
14:00:00	14:15:00	-	-	18	7	31	60	507	61	75	24	2,307	3,090
14:15:00	14:30:00	-	-	21	13	26	50	415	58	89	25	1,725	2,422
14:30:00	14:45:00	-	-	33	10	38	54	446	69	87	28	1,853	2,618
14:45:00	15:00:00	-	-	20	10	27	43	409	68	88	24	1,881	2,570
15:00:00	15:15:00	-	-	10	7	42	55	432	69	88	25	2,269	2,997
15:15:00	15:30:00	-	-	17	11	28	38	455	66	73	33	1,875	2,596
15:30:00	15:45:00	-	-	15	11	40	56	495	52	80	30	2,176	2,955
15:45:00	16:00:00	-	-	20	12	51	39	434	40	86	27	1,958	2,667
16:00:00	16:15:00	-	-	13	5	41	34	394	28	73	24	1,646	2,258
16:15:00	16:30:00	-	-	5	10	30	26	390	24	84	19	1,588	2,176
16:30:00	16:45:00	-	-	12	13	35	35	426	31	70	22	1,937	2,581
16:45:00	17:00:00	-	-	5	8	30	39	458	16	80	21	1,806	2,463
17:00:00	17:15:00	-	-	3	12	42	41	380	31	92	23	1,920	2,544
17:15:00	17:30:00	-	1	4	8	32	40	380	24	107	18	2,033	2,647
17:30:00	17:45:00	-	-	-	8	30	31	383	18	98	22	2,130	2,720
17:45:00	18:00:00	-	-	3	8	24	28	390	20	106	16	1,888	2,483
18:00:00	18:15:00	-	-	1	9	26	25	424	19	50	19	1,871	2,444
18:15:00	18:30:00	-	1	1	13	23	36	445	21	63	19	1,885	2,507
18:30:00	18:45:00	-	-	3	18	20	36	450	31	50	12	1,743	2,363
18:45:00	19:00:00	-	1	2	10	21	37	413	34	58	10	1,543	2,129
19:00:00	19:15:00	-	-	1	14	13	40	380	60	41	13	1,507	2,069
19:15:00	19:30:00	-	-	1	6	11	27	378	38	35	7	1,375	1,878
19:30:00	19:45:00	-	1	1	8	5	31	357	35	36	5	1,239	1,718
19:45:00	20:00:00	-	-	3	8	6	22	327	30	41	4	1,126	1,567
20:00:00	20:15:00	-	2	12	4	4	23	332	24	45	1	990	1,437
20:15:00	20:30:00	1	3	14	2	3	19	296	32	37	3	829	1,239
20:30:00	20:45:00	1	1	12	6	3	13	276	29	20	2	722	1,085
20:45:00	21:00:00	-	-	11	1	1	11	239	25	36	-	609	933

Start Time	End Time	Multi Axle Truck	Heavy Truck	Light Truck	Standard Bus	Mini Bus	Micro Bus	Car / Taxi	Utility Vehicle	Four Wheel Drive	Motorized Three-Wheeler	Motor Cycle	Total
21:00:00	21:15:00	-	3	27	1	1	13	243	23	22	-	561	894
21:15:00	21:30:00	2	1	17	3	3	13	239	23	22	1	459	783
21:30:00	21:45:00	1	3	19	-	1	10	219	17	23	1	383	677
21:45:00	22:00:00	-	5	20	-	-	13	186	10	19	-	333	586
22:00:00	22:15:00	-	1	6	-	-	-	42	3	4	-	76	132
Total		**5**	**25**	**696**	**480**	**1,762**	**2,564**	**24,609**	**2,666**	**4,115**	**1,382**	**100,486**	**138,790**

Appendix A.4: 15 minutes classified vehicle counts for Day-4

Start Time	End Time	Multi Axle Truck	Heavy Truck	Light Truck	Standard Bus	Mini Bus	Micro Bus	Car / Taxi	Utility Vehicle	Four Wheel Drive	Motorized Three-Wheeler	Motor Cycle	Total
5:45:00	6:00:00	-	2	8	4	6	16	103	34	5	6	426	610
6:00:00	6:15:00	-	5	3	11	10	38	142	45	19	17	776	1,066
6:15:00	6:30:00	-	3	7	17	5	52	195	40	21	22	928	1,290
6:30:00	6:45:00	-	2	7	19	11	47	180	53	27	23	873	1,242
6:45:00	7:00:00	-	5	5	21	4	39	157	45	26	18	929	1,249
7:00:00	7:15:00	-	1	3	20	4	36	138	37	25	22	612	898
7:15:00	7:30:00	-	5	3	15	5	34	111	27	28	13	497	738
7:30:00	7:45:00	-	2	3	33	10	40	228	60	40	22	665	1,103
7:45:00	8:00:00	-	1	2	27	4	47	215	40	46	16	815	1,213
8:00:00	8:15:00	-	2	7	21	5	34	273	56	65	14	931	1,408
8:15:00	8:30:00	-	1	10	23	7	43	268	41	64	24	882	1,363
8:30:00	8:45:00	-	5	10	32	10	51	353	46	65	26	965	1,563
8:45:00	9:00:00	-	1	10	19	5	37	353	43	90	26	1,170	1,754
9:00:00	9:15:00	-	1	10	14	11	41	406	51	102	23	1,335	1,994
9:15:00	9:30:00	1	-	10	10	15	44	395	35	93	22	1,351	1,976
9:30:00	9:45:00	-	1	13	18	14	47	430	56	126	33	1,487	2,225
9:45:00	10:00:00	-	4	7	16	12	55	360	28	87	30	1,493	2,092
10:00:00	10:15:00	-	1	5	19	8	49	452	47	88	39	1,539	2,247
10:15:00	10:30:00	-	-	5	26	2	49	404	49	62	32	1,475	2,104
10:30:00	10:45:00	-	1	9	22	9	55	441	48	75	31	1,527	2,218
10:45:00	11:00:00	-	-	5	24	9	52	429	40	74	27	1,549	2,209
11:00:00	11:15:00	-	1	1	17	4	53	402	59	62	29	1,503	2,131
11:15:00	11:30:00	-	-	17	27	7	47	441	69	86	30	1,456	2,180
11:30:00	11:45:00	-	2	3	22	5	46	432	60	75	29	1,288	1,962
11:45:00	12:00:00	-	1	5	19	6	47	438	59	77	25	1,254	1,931
12:00:00	12:15:00	-	2	6	24	6	48	427	55	80	25	1,471	2,144
12:15:00	12:30:00	-	1	9	18	6	47	485	57	66	25	1,113	1,827
12:30:00	12:45:00	-	1	7	21	7	44	433	41	73	29	961	1,617
12:45:00	13:00:00	-	3	2	21	6	56	465	32	86	23	1,075	1,769

Start Time	End Time	Multi Axle Truck	Heavy Truck	Light Truck	Standard Bus	Mini Bus	Micro Bus	Car / Taxi	Utility Vehicle	Four Wheel Drive	Motorized Three-Wheeler	Motor Cycle	Total
13:00:00	13:15:00	-	-	5	14	6	49	432	44	68	25	1,216	1,859
13:15:00	13:30:00	-	-	4	18	6	36	444	43	60	29	1,199	1,839
13:30:00	13:45:00	-	-	7	22	5	52	448	48	67	26	1,390	2,065
13:45:00	14:00:00	-	1	-	20	9	50	414	32	76	27	1,430	2,059
14:00:00	14:15:00	-	3	9	15	4	49	449	46	76	26	1,338	2,015
14:15:00	14:30:00	-	2	10	16	4	58	466	52	66	32	1,494	2,200
14:30:00	14:45:00	-	1	4	28	6	63	419	50	72	29	1,372	2,044
14:45:00	15:00:00	-	7	4	27	5	48	446	37	77	22	1,327	2,000
15:00:00	15:15:00	-	2	7	19	5	51	449	52	72	33	1,352	2,042
15:15:00	15:30:00	-	3	7	25	5	47	436	52	66	32	1,376	2,049
15:30:00	15:45:00	-	2	10	29	5	46	432	39	81	26	1,327	1,997
15:45:00	16:00:00	-	1	4	20	3	52	453	49	72	24	1,357	2,035
16:00:00	16:15:00	-	-	7	23	4	35	417	23	43	18	1,260	1,830
16:15:00	16:30:00	-	-	8	19	6	41	405	30	71	16	1,368	1,964
16:30:00	16:45:00	-	-	6	13	3	24	361	38	78	13	1,299	1,835
16:45:00	17:00:00	-	-	3	12	2	21	207	19	60	17	836	1,177
17:00:00	17:15:00	-	-	8	34	11	41	474	35	77	18	1,527	2,225
17:15:00	17:30:00	-	2	4	24	6	45	448	30	49	16	1,398	2,022
17:30:00	17:45:00	-	-	1	7	-	27	179	22	63	7	764	1,070
17:45:00	18:00:00	2	1	10	32	3	43	606	41	89	17	1,565	2,409
18:00:00	18:15:00	3	1	10	25	1	42	484	39	64	16	1,282	1,967
18:15:00	18:30:00	-	3	6	26	6	35	459	25	45	15	1,212	1,832
18:30:00	18:45:00	-	-	5	25	-	41	403	33	79	9	1,199	1,794
18:45:00	19:00:00	-	-	6	14	1	41	413	28	52	16	1,039	1,610
19:00:00	19:15:00	-	-	11	16	2	48	402	32	66	17	1,100	1,694
19:15:00	19:30:00	-	2	4	10	2	32	380	43	45	10	1,006	1,534
19:30:00	19:45:00	-	6	8	9	2	35	381	35	58	8	1,026	1,568
19:45:00	20:00:00	-	3	5	8	2	23	341	17	48	4	1,029	1,480
20:00:00	20:15:00	1	1	17	8	-	18	321	25	45	3	834	1,273
20:15:00	20:30:00	-	5	9	6	-	17	349	33	52	1	798	1,270
20:30:00	20:45:00	-	1	8	2	-	14	320	22	50	-	688	1,105
20:45:00	21:00:00	-	2	5	3	-	5	332	17	44	1	613	1,022

Start Time	End Time	Multi Axle Truck	Heavy Truck	Light Truck	Standard Bus	Mini Bus	Micro Bus	Car / Taxi	Utility Vehicle	Four Wheel Drive	Motorized Three-Wheeler	Motor Cycle	Total
21:00:00	21:15:00	-	26	6	5	-	7	336	10	43	-	501	934
21:15:00	21:30:00	-	20	5	2	-	13	290	26	31	-	462	849
21:30:00	21:45:00	2	10	3	1	-	6	294	16	33	-	382	747
21:45:00	22:00:00	-	16	2	-	-	3	284	16	32	-	346	699
22:00:00	22:15:00	1	8	1	-	-	1	175	9	10	-	218	423
Total		**10**	**183**	**421**	**1,157**	**327**	**2,553**	**23,905**	**2,561**	**4,013**	**1,254**	**72,276**	**108,660**

Appendix A.5: 15 minutes classified vehicle counts for Day-5

Start Time	End Time	Multi Axle Truck	Heavy Truck	Light Truck	Standard Bus	Mini Bus	Micro Bus	Car / Taxi	Utility Vehicle	Four Wheel Drive	Motorized Three-Wheeler	Motor Cycle	Total
6:00:00	6:15:00	-	-	3	19	4	23	107	26	9	18	545	754
6:15:00	6:30:00	-	-	4	15	13	34	166	38	14	22	780	1,086
6:30:00	6:45:00	1	2	8	24	12	35	153	38	24	28	828	1,153
6:45:00	7:00:00	-	3	3	34	9	34	189	35	37	30	963	1,337
7:00:00	7:15:00	-	1	5	28	9	35	207	38	32	21	956	1,332
7:15:00	7:30:00	1	1	4	29	14	45	229	36	42	24	993	1,418
7:30:00	7:45:00	-	-	7	28	12	31	304	45	58	27	1,093	1,605
7:45:00	8:00:00	-	4	4	32	9	39	270	38	48	26	1,102	1,572
8:00:00	8:15:00	-	-	6	18	13	38	265	46	53	31	1,048	1,518
8:15:00	8:30:00	-	2	7	34	7	33	324	34	58	26	1,093	1,618
8:30:00	8:45:00	-	1	4	36	12	37	333	39	53	25	1,137	1,677
8:45:00	9:00:00	-	1	5	27	7	44	368	43	66	29	1,332	1,922
9:00:00	9:15:00	-	-	3	23	9	39	356	33	73	34	1,434	2,004
9:15:00	9:30:00	-	2	6	21	14	33	376	27	84	35	1,689	2,287
9:30:00	9:45:00	-	-	4	26	10	39	379	30	89	37	1,957	2,571
9:45:00	10:00:00	-	-	3	20	10	40	383	21	78	45	2,117	2,717
10:00:00	10:15:00	-	-	2	20	11	41	421	33	64	37	2,155	2,784
10:15:00	10:30:00	-	-	5	18	13	41	448	33	87	40	2,027	2,712
10:30:00	10:45:00	-	1	3	25	10	41	433	37	76	33	1,824	2,483
10:45:00	11:00:00	-	-	6	21	15	37	445	51	90	33	1,880	2,578
11:00:00	11:15:00	-	-	2	23	8	33	452	43	97	40	1,904	2,602
11:15:00	11:30:00	-	1	6	24	4	39	461	47	95	29	1,840	2,546
11:30:00	11:45:00	-	1	5	21	10	44	455	68	85	36	1,921	2,646
11:45:00	12:00:00	-	1	4	22	9	39	454	64	94	33	1,968	2,688
12:00:00	12:15:00	-	1	3	20	12	40	480	62	105	21	1,970	2,714
12:15:00	12:30:00	-	-	4	24	8	33	435	59	88	26	1,963	2,640
12:30:00	12:45:00	-	-	5	24	9	39	448	73	91	31	2,025	2,745
12:45:00	13:00:00	-	1	3	23	8	34	442	66	107	32	1,953	2,669
13:00:00	13:15:00	-	1	6	21	7	39	447	69	96	24	1,817	2,527

Start Time	End Time	Multi Axle Truck	Heavy Truck	Light Truck	Standard Bus	Mini Bus	Micro Bus	Car / Taxi	Utility Vehicle	Four Wheel Drive	Motorized Three-Wheeler	Motor Cycle	Total
13:15:00	13:30:00	-	1	6	22	10	36	507	69	117	27	1,453	2,248
13:30:00	13:45:00	-	-	7	24	6	38	541	80	117	35	1,289	2,137
13:45:00	14:00:00	-	1	5	24	10	34	471	57	104	24	1,078	1,808
14:00:00	14:15:00	-	1	11	20	9	33	465	41	93	18	1,176	1,867
14:15:00	14:30:00	-	1	7	16	8	36	506	50	112	26	1,392	2,154
14:30:00	14:45:00	-	2	9	23	13	28	499	58	120	28	1,595	2,375
14:45:00	15:00:00	-	-	4	22	6	36	507	65	106	27	1,608	2,381
15:00:00	15:15:00	-	-	6	22	8	29	496	51	131	29	1,647	2,419
15:15:00	15:30:00	-	-	1	22	5	39	502	51	93	34	1,572	2,319
15:30:00	15:45:00	-	-	9	20	7	37	478	49	102	26	1,578	2,306
15:45:00	16:00:00	-	1	-	20	13	34	454	54	111	28	1,485	2,200
16:00:00	16:15:00	-	-	5	21	12	34	455	41	107	25	1,536	2,236
16:15:00	16:30:00	-	-	1	19	12	39	477	44	112	20	1,576	2,300
16:30:00	16:45:00	-	1	4	22	8	36	494	45	108	37	1,704	2,459
16:45:00	17:00:00	-	-	3	27	8	35	462	48	140	29	1,621	2,373
17:00:00	17:15:00	-	-	8	17	9	41	442	33	121	22	1,606	2,299
17:15:00	17:30:00	-	-	5	25	5	45	476	32	126	24	1,735	2,473
17:30:00	17:45:00	-	-	2	17	12	37	459	34	122	25	1,716	2,424
17:45:00	18:00:00	-	1	7	24	12	39	465	27	107	16	1,735	2,433
18:00:00	18:15:00	-	-	5	17	8	34	415	30	99	19	1,782	2,409
18:15:00	18:30:00	-	-	3	28	10	37	430	39	108	20	1,698	2,373
18:30:00	18:45:00	-	-	8	18	8	36	372	23	139	14	1,462	2,080
18:45:00	19:00:00	-	-	5	13	8	32	363	35	105	16	1,327	1,904
19:00:00	19:15:00	1	1	6	25	9	29	331	30	100	12	1,347	1,891
19:15:00	19:30:00	-	1	10	13	4	26	348	31	88	8	1,368	1,897
19:30:00	19:45:00	-	1	4	13	2	30	353	33	90	4	1,309	1,839
19:45:00	20:00:00	-	1	5	5	-	20	339	30	82	5	1,152	1,639
20:00:00	20:15:00	-	1	9	8	2	15	338	25	75	1	1,077	1,551
20:15:00	20:30:00	1	1	13	4	-	14	321	33	64	2	887	1,340
20:30:00	20:45:00	-	4	7	3	-	11	259	30	71	1	668	1,054
20:45:00	21:00:00	1	-	11	2	-	7	268	26	59	-	587	961
21:00:00	21:15:00	-	7	8	-	1	4	231	19	53	-	525	848

Start Time	End Time	Multi Axle Truck	Heavy Truck	Light Truck	Standard Bus	Mini Bus	Micro Bus	Car / Taxi	Utility Vehicle	Four Wheel Drive	Motorized Three-Wheeler	Motor Cycle	Total
21:15:00	21:30:00	-	16	8	-	3	3	227	15	58	1	475	806
21:30:00	21:45:00	-	19	5	-	-	4	228	15	43	-	398	712
21:45:00	22:00:00	-	21	5	-	1	3	171	17	33	-	335	586
22:00:00	22:15:00	-	4	1	-	-	3	66	1	15	-	125	215
Total		**5**	**110**	**343**	**1,256**	**517**	**2,073**	**24,446**	**2,633**	**5,424**	**1,476**	**89,938**	**128,221**

Appendix B: Cruise Speed Survey

Appendix B.1: Cruise Speed Survey for Kupondole Leg

Baseline Length = 30 m				
SN	**Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
1	12:14:18	B	7.0	15.4
2	12:14:58	MC	3.2	34.1
3	12:16:09	McB	5.4	20.0
4	12:16:59	B	5.9	18.4
5	12:17:36	3W	3.6	29.9
6	12:18:28	3W	3.8	28.1
7	12:19:25	B	6.3	17.1
8	12:20:07	B	8.3	13.0
9	12:20:40	J	4.5	23.8
10	12:21:47	3W	3.8	28.5
11	12:22:36	C	4.2	25.9
12	12:23:50	MC	3.1	35.2
13	12:24:34	MC	3.1	34.5
14	12:25:30	MC	3.2	34.2
15	12:26:06	J	4.6	23.5
16	12:26:40	MC	2.9	36.8
17	12:27:47	3W	3.9	28.0
18	12:28:41	J	4.6	23.7
19	12:29:56	3W	3.6	30.0
20	12:30:56	MC	3.2	33.6

Baseline Length = 30 m				
SN	**Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
21	12:31:40	MC	3.4	32.1
22	12:32:25	B	6.2	17.4
23	12:33:38	C	4.3	25.2
24	12:34:36	C	4.0	26.9
25	12:35:23	MC	3.4	32.1
26	12:36:36	McB	5.4	20.2
27	12:37:19	MC	3.3	33.0
28	12:38:06	McB	5.3	20.4
29	12:38:39	B	5.8	18.7
30	12:39:25	3W	3.7	29.2
31	12:40:17	MC	3.1	35.3
32	12:41:31	MC	3.0	36.0
33	12:42:08	J	4.6	23.4
34	12:43:09	C	4.0	27.0
35	12:43:55	C	4.0	26.8
36	12:44:43	C	4.3	24.9
37	12:45:55	MC	3.1	35.2
38	12:46:33	MC	3.3	33.0
39	12:47:22	J	4.5	23.9
40	12:48:19	MC	3.5	31.0

Baseline Length = 30 m				
SN	**Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
41	12:49:31	MC	3.4	31.9
42	12:50:27	B	6.0	17.9
43	12:51:29	MC	3.2	33.4
44	12:52:33	3W	3.5	30.8
45	12:53:14	C	4.2	25.5
46	12:53:52	McB	5.5	19.8
47	12:54:58	B	5.5	19.5
48	12:55:50	C	4.3	25.2
49	12:56:44	J	4.6	23.3
50	12:57:47	MC	3.2	33.4
51	12:58:24	C	4.0	26.7
52	12:58:55	3W	4.0	27.1
53	12:59:58	3W	3.6	29.9
54	13:01:05	B	6.2	17.3
55	13:02:05	3W	3.9	27.4
56	13:02:35	J	4.6	23.3
57	13:03:32	3W	3.7	29.0
58	13:04:46	MC	2.8	37.9
59	13:05:48	J	4.9	22.3
60	13:06:25	C	4.4	24.6
61	13:07:01	MC	3.4	31.9
62	13:07:56	McB	5.0	21.5
63	13:08:41	B	5.7	19.0
64	13:09:40	McB	5.0	21.4

Baseline Length = 30 m				
SN	**Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
65	13:10:11	3W	3.9	27.4
66	13:10:50	C	4.4	24.7
67	13:11:21	MC	3.1	34.8
68	13:11:56	MC	3.3	33.0
69	13:12:38	J	4.8	22.4
70	13:13:37	C	4.2	25.5
71	13:14:45	McB	5.2	20.6
72	13:15:54	3W	3.5	30.8
73	13:16:30	3W	3.8	28.2
74	13:17:04	3W	4.0	27.3
75	13:17:40	C	4.4	24.3
76	13:18:41	3W	3.9	28.0
77	13:19:40	MC	3.5	31.2
78	13:20:20	MC	3.1	34.6
79	13:21:15	C	4.2	26.0
80	13:21:45	McB	5.3	20.3
81	13:22:38	C	4.3	25.3
82	13:23:28	B	5.8	18.6
83	13:24:38	MC	3.4	31.7
84	13:25:10	B	5.6	19.2
85	13:26:25	3W	3.9	28.0
86	13:27:20	McB	5.2	20.7
87	13:28:11	3W	3.6	30.2
88	13:28:41	J	4.5	23.8

Baseline Length = 30 m				
SN	**Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
89	13:29:26	J	4.7	23.0
90	13:30:16	3W	3.7	29.3
91	13:31:21	C	4.0	26.8
92	13:32:26	J	4.8	22.3

Baseline Length = 30 m				
SN	**Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
93	13:33:10	C	4.1	26.1
94	13:34:19	J	4.8	22.6
95	13:35:23	C	4.1	26.3
96	13:36:12	J	4.5	23.8

Appendix B.2: Cruise Speed Survey for Maternity Road Leg

Baseline Length = 30 m				
SN	**Clock Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
1	12:32:50	C	4.6	23.6
2	12:34:01	C	4.6	23.6
3	12:34:31	C	4.8	22.3
4	12:35:07	C	4.7	22.8
5	12:36:15	MC	3.5	30.6
6	12:37:13	MC	3.7	29.0
7	12:38:18	C	5.0	21.7
8	12:39:20	C	4.5	24.0
9	12:40:05	J	5.4	20.2
10	12:40:56	C	4.2	25.7
11	12:41:59	C	4.0	26.7
12	12:42:55	MC	3.7	29.4
13	12:43:33	MC	3.9	27.8
14	12:44:25	C	4.5	24.0
15	12:45:15	J	5.5	19.8
16	12:46:23	J	5.7	18.9
17	12:47:02	MC	3.9	27.4
18	12:47:57	C	4.3	25.4
19	12:48:45	C	5.0	21.7
20	12:49:34	C	5.0	21.8
21	12:50:25	MC	3.8	28.6
22	12:51:38	C	4.4	24.3
23	12:52:15	MC	3.8	28.1
24	12:53:18	MC	3.7	29.3
25	12:54:29	C	4.8	22.4
26	12:55:03	C	4.3	24.9
27	12:56:10	C	4.3	25.1

Baseline Length = 30 m				
SN	**Clock Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
28	12:56:47	MC	3.7	28.9
29	12:57:21	MC	3.8	28.5
30	12:58:09	J	5.2	20.7
31	12:58:44	C	4.9	22.1
32	12:59:57	MC	3.9	27.9
33	13:00:29	C	4.8	22.7
34	13:01:40	C	4.1	26.4
35	13:02:50	C	4.4	24.6
36	13:03:51	C	5.0	21.6
37	13:05:06	C	4.4	24.7
38	13:06:12	MC	3.6	29.9
39	13:06:58	J	5.2	20.8
40	13:08:07	C	4.1	26.3
41	13:08:37	MC	4.0	27.1
42	13:09:29	C	4.1	26.5
43	13:10:20	J	5.2	20.8
44	13:11:30	C	4.1	26.4
45	13:12:29	C	4.8	22.5
46	13:13:06	C	4.6	23.6
47	13:14:03	C	4.4	24.5
48	13:15:00	C	4.0	26.8
49	13:15:32	MC	3.3	32.7
50	13:16:05	C	4.7	23.1
51	13:16:54	C	4.4	24.7
52	13:17:26	J	6.9	15.6
53	13:17:57	C	4.3	25.1
54	13:18:56	MC	3.8	28.6
55	13:19:57	J	5.7	18.8

Baseline Length = 30 m				
SN	**Clock Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
56	13:20:59	J	5.8	18.7
57	13:22:06	J	5.1	21.1
58	13:23:15	C	4.4	24.7
59	13:23:49	C	4.3	25.0
60	13:24:46	C	4.4	24.7
61	13:25:17	MC	3.9	27.6
62	13:25:50	C	4.4	24.8
63	13:26:22	J	5.2	20.6
64	13:27:16	C	4.5	23.8
65	13:27:49	J	5.4	19.9
66	13:28:51	C	4.5	23.9
67	13:29:52	MC	3.7	28.8
68	13:30:56	MC	4.0	27.2
69	13:32:10	MC	3.9	28.0
70	13:33:06	MC	3.4	31.7
71	13:33:44	MC	3.8	28.1
72	13:34:27	C	4.6	23.5
73	13:35:03	C	5.0	21.8
74	13:35:34	MC	3.4	32.0
75	13:36:19	J	7.6	14.2
76	13:36:49	C	4.0	26.9

Baseline Length = 30 m				
SN	**Clock Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
77	13:37:47	MC	3.8	28.7
78	13:38:28	C	4.5	24.1
79	13:39:03	C	4.0	26.8
80	13:39:55	C	4.3	25.3
81	13:41:03	J	5.0	21.4
82	13:41:42	J	6.1	17.8
83	13:42:46	C	4.7	23.0
84	13:43:47	MC	3.7	29.0
85	13:44:23	MC	3.8	28.1
86	13:45:20	C	4.4	24.4
87	13:46:02	J	5.7	18.9
88	13:46:59	C	4.4	24.5
89	13:47:36	C	4.7	23.1
90	13:48:24	C	4.3	25.1
91	13:49:30	C	4.6	23.3
92	13:50:36	C	4.2	25.4
93	13:51:30	C	4.3	25.1
94	13:52:12	C	4.8	22.3
95	13:53:01	MC	3.8	28.6
96	13:53:46	C	4.2	25.4
97	13:54:42	C	4.5	24.1

Appendix B.3: Cruise Speed Survey for Maitighar Leg

Baseline Length = 30 m				
SN	**Clock Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
1	13:28:54	3W	3.6	29.8
2	13:30:01	J	4.7	22.8
3	13:30:39	B	5.7	19.1
4	13:31:46	3W	4.0	27.1
5	13:32:28	C	4.0	26.9
6	13:32:58	3W	3.8	28.1
7	13:33:39	J	4.5	23.9
8	13:34:39	MC	3.0	35.6
9	13:35:09	C	4.0	26.7
10	13:35:52	J	4.5	23.7
11	13:36:25	C	4.3	25.1
12	13:37:00	3W	3.5	30.7
13	13:37:55	3W	3.8	28.6
14	13:39:04	MC	3.3	33.1
15	13:39:55	3W	3.7	29.1
16	13:40:51	3W	3.8	28.3
17	13:41:55	C	4.3	25.2
18	13:42:30	McB	5.4	20.1
19	13:43:36	McB	5.2	20.7
20	13:44:16	3W	3.8	28.7
21	13:45:04	McB	5.2	20.8
22	13:45:42	3W	3.9	27.6

Baseline Length = 30 m				
SN	**Clock Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
23	13:46:56	C	4.3	25.1
24	13:47:30	3W	3.7	29.0
25	13:48:21	3W	4.0	27.3
26	13:49:21	3W	4.0	27.0
27	13:50:09	C	4.4	24.5
28	13:51:21	J	4.9	22.1
29	13:52:11	3W	3.9	28.0
30	13:53:03	C	4.0	26.8
31	13:53:57	C	4.4	24.6
32	13:54:56	3W	3.9	27.9
33	13:56:01	B	5.8	18.6
34	13:56:48	J	4.8	22.5
35	13:57:37	B	5.7	19.1
36	13:58:37	C	4.1	26.2
37	13:59:32	McB	5.3	20.3
38	14:00:23	3W	3.9	28.0
39	14:01:29	J	5.0	21.7
40	14:02:20	MC	3.3	33.2
41	14:03:35	3W	3.5	30.8
42	14:04:24	J	4.9	21.9
43	14:05:32	J	5.0	21.7
44	14:06:29	MC	3.2	33.5

Baseline Length = 30 m				
SN	**Clock Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
45	14:07:34	C	4.1	26.3
46	14:08:08	MC	3.1	34.6
47	14:09:23	3W	4.0	27.1
48	14:10:33	C	4.5	24.1
49	14:11:35	J	4.7	22.9
50	14:12:41	C	4.4	24.5
51	14:13:25	3W	3.9	27.4
52	14:14:15	C	4.2	25.6
53	14:14:54	McB	5.4	20.0
54	14:15:32	3W	3.6	30.1
55	14:16:43	McB	5.1	21.2
56	14:17:32	C	4.4	24.7
57	14:18:32	3W	3.5	30.5
58	14:19:18	MC	3.4	32.2
59	14:20:16	C	4.2	25.7
60	14:20:46	3W	3.6	29.7
61	14:21:21	3W	3.9	27.9
62	14:21:51	J	4.6	23.7
63	14:22:45	C	4.3	25.1
64	14:23:37	B	6.3	17.2
65	14:24:48	C	4.0	26.7
66	14:25:44	C	4.2	25.6
67	14:26:51	3W	3.7	29.2
68	14:27:45	MC	2.9	37.8

Baseline Length = 30 m				
SN	**Clock Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
69	14:28:55	McB	5.2	20.8
70	14:29:40	McB	5.2	20.6
71	14:30:33	3W	3.8	28.6
72	14:31:36	J	4.6	23.3
73	14:32:38	MC	3.4	32.2
74	14:33:28	MC	3.3	33.0
75	14:34:34	MC	3.5	31.1
76	14:35:16	3W	3.9	27.7
77	14:35:56	C	4.3	25.2
78	14:36:45	J	4.8	22.4
79	14:37:47	B	6.1	17.6
80	14:38:39	C	4.2	25.6
81	14:39:35	C	4.1	26.7
82	14:40:40	3W	3.9	27.9
83	14:41:52	C	4.5	24.1
84	14:42:24	C	4.2	25.8
85	14:43:04	MC	3.3	33.0
86	14:44:19	C	4.3	25.4
87	14:45:19	C	4.4	24.8
88	14:46:07	3W	3.9	27.5
89	14:47:08	3W	3.5	30.5
90	14:47:49	3W	3.6	29.8
91	14:48:42	C	4.0	27.0
92	14:49:16	3W	3.6	29.6

Baseline Length = 30 m				
SN	**Clock Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
93	14:49:59	C	4.2	25.6
94	14:50:56	McB	5.0	21.6
95	14:51:38	C	4.2	25.9
96	14:52:51	3W	3.9	27.9
97	14:53:49	C	4.4	24.4
98	14:54:30	C	4.2	25.5
99	14:55:38	J	4.6	23.3

Baseline Length = 30 m				
SN	**Clock Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
100	14:56:23	3W	3.7	29.6
101	14:57:20	3W	3.9	27.9
102	14:58:27	3W	3.9	27.9
103	14:59:15	C	4.3	25.4
104	15:00:28	MC	3.3	32.9
105	15:01:21	3W	3.9	27.7

Appendix B.4 Cruise Speed Survey for Tripureshwor Leg

Baseline Length = 30 m				
SN	**Clock Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
1	14:14:56	C	4.0	26.7
2	14:15:58	MC	3.0	36.3
3	14:16:32	MC	2.8	39.1
4	14:17:15	MC	3.5	31.1
5	14:18:26	3W	3.7	29.5
6	14:19:01	McB	5.3	20.3
7	14:19:32	C	4.3	25.4
8	14:20:21	MC	3.4	31.7
9	14:21:12	McB	5.4	19.9
10	14:22:04	MC	3.4	31.5
11	14:22:49	3W	3.9	27.6
12	14:24:01	C	4.2	25.9
13	14:24:35	3W	3.8	28.4
14	14:25:18	McB	5.2	20.7
15	14:25:58	C	4.1	26.6
16	14:26:33	B	5.5	19.6
17	14:27:12	MC	3.4	32.0
18	14:27:49	MC	3.4	31.4
19	14:28:53	MC	3.0	35.8
20	14:29:28	MC	3.1	34.9
21	14:30:29	MC	3.2	33.5
22	14:31:37	MC	3.4	31.5

Baseline Length = 30 m				
SN	**Clock Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
23	14:32:46	J	4.7	23.1
24	14:33:33	MC	3.2	33.7
25	14:34:47	3W	3.6	29.9
26	14:35:39	McB	5.2	20.6
27	14:36:14	J	4.5	24.0
28	14:37:01	3W	3.8	28.7
29	14:38:16	3W	3.6	30.0
30	14:39:16	MC	2.9	37.8
31	14:40:09	MC	2.8	38.1
32	14:41:24	C	4.2	25.7
33	14:42:01	3W	3.6	30.2
34	14:43:07	MC	3.1	34.5
35	14:44:00	MC	3.4	31.9
36	14:45:10	C	4.4	24.3
37	14:45:50	MC	3.3	33.1
38	14:46:35	MC	3.2	33.9
39	14:47:50	McB	5.2	20.8
40	14:48:30	MC	3.5	31.2
41	14:49:08	MC	3.2	34.0
42	14:49:47	B	5.5	19.6
43	14:50:17	J	4.9	22.0
44	14:51:15	MC	3.5	31.0

Baseline Length = 30 m				
SN	**Clock Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
45	14:52:04	MC	3.1	34.8
46	14:53:08	3W	3.5	30.7
47	14:54:22	MC	3.5	30.9
48	14:55:13	3W	3.6	30.2
49	14:56:01	MC	3.4	32.0
50	14:56:43	C	4.3	25.0
51	14:57:13	C	4.2	25.8
52	14:57:56	MC	3.3	32.4
53	14:58:28	C	4.3	25.4
54	14:59:24	3W	3.8	28.6
55	15:00:32	MC	2.8	38.4
56	15:01:07	3W	3.9	27.5
57	15:01:37	3W	3.8	28.3
58	15:02:08	MC	3.0	35.7
59	15:02:48	MC	3.3	32.3
60	15:03:27	MC	3.4	31.5
61	15:04:06	C	4.1	26.2
62	15:05:13	MC	3.0	36.0
63	15:06:02	C	4.0	27.0
64	15:07:08	MC	3.5	31.0
65	15:08:13	MC	3.1	35.0
66	15:08:52	3W	3.6	29.9
67	15:09:57	MC	3.3	32.5
68	15:10:39	3W	3.6	30.1

Baseline Length = 30 m				
SN	**Clock Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
69	15:11:32	3W	3.6	30.0
70	15:12:02	3W	3.9	27.8
71	15:12:45	3W	3.8	28.1
72	15:13:49	3W	3.8	28.4
73	15:15:03	MC	3.0	35.7
74	15:15:57	J	4.6	23.5
75	15:16:57	MC	3.4	31.8
76	15:17:53	MC	3.3	33.2
77	15:18:48	MC	2.9	36.8
78	15:19:22	3W	3.8	28.5
79	15:20:26	MC	3.4	31.4
80	15:21:13	MC	3.4	32.0
81	15:21:48	C	4.1	26.6
82	15:22:46	J	4.8	22.3
83	15:23:37	C	4.0	26.9
84	15:24:52	3W	4.0	27.2
85	15:25:46	MC	3.0	35.5
86	15:26:55	MC	2.8	38.9
87	15:27:48	MC	3.2	34.2
88	15:28:32	3W	3.6	29.8
89	15:29:47	MC	3.0	36.4
90	15:30:50	MC	3.5	31.0
91	15:31:28	MC	3.4	31.4
92	15:32:15	MC	3.3	32.8

Baseline Length = 30 m				
SN	**Clock Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
93	15:33:08	C	4.2	26.0
94	15:33:50	C	4.1	26.6
95	15:34:48	MC	2.9	37.2
96	15:35:48	3W	3.7	29.5
97	15:37:02	B	6.9	15.7
98	15:38:07	J	4.7	23.0

Baseline Length = 30 m				
SN	**Clock Time**	**Vehicle Type**	**Time Taken (sec)**	**Speed (kmph)**
99	15:38:37	MC	3.2	33.8
100	15:39:39	MC	3.1	35.2
101	15:40:20	MC	3.2	33.3
102	15:40:48	MC	3.3	32.4
103	15:41:46	3W	3.6	30.4
104	15:42:16	MC	3.2	34.0

Appendix C: Phasing and Timing Observations

Appendix C.1: Phasing and Timing Observations for Day-1

Cycle	Phase	Start Time	End Time	Duration
1	P1	9:14:25	9:14:51	0:00:26
	P2	9:14:51	9:15:23	0:00:32
	P1	9:15:23	9:15:28	0:00:05
	P2	9:15:28	9:15:43	0:00:15
	P1	9:15:43	9:15:50	0:00:07
	P2	9:15:50	9:16:19	0:00:29
	P1	9:16:19	9:16:23	0:00:04
	P2	9:16:23	9:16:59	0:00:36
	P1	9:16:59	9:17:07	0:00:08
	P2	9:17:07	9:17:15	0:00:08
	P1	9:17:15	9:17:17	0:00:02
	P2	9:17:17	9:17:30	0:00:13
	P1	9:17:30	9:17:35	0:00:05
	P2	9:17:35	9:17:46	0:00:11
	P1	9:17:46	9:17:56	0:00:10
	P3	9:17:56	9:18:16	0:00:20
	P4	9:18:16	9:18:21	0:00:05
	P3	9:18:21	9:18:34	0:00:13
	P4	9:18:34	9:18:37	0:00:03
	P3	9:18:37	9:18:41	0:00:04
	P4	9:18:41	9:19:13	0:00:32
	P3	9:19:13	9:19:30	0:00:17
	P4	9:19:30	9:19:53	0:00:23

Cycle	Phase	Start Time	End Time	Duration
	P3	9:19:53	9:19:59	0:00:06
	P4	9:19:59	9:20:06	0:00:07
	P5	9:20:06	9:21:48	0:01:42
2	P2	9:21:48	9:22:36	0:00:48
	P1	9:22:36	9:22:43	0:00:07
	P2	9:22:43	9:22:56	0:00:13
	P1	9:22:56	9:23:12	0:00:16
	P2	9:23:12	9:23:36	0:00:24
	P1	9:23:36	9:23:45	0:00:09
	P2	9:23:45	9:23:57	0:00:12
	P1	9:23:57	9:24:08	0:00:11
	P2	9:24:08	9:24:21	0:00:13
	P1	9:24:21	9:24:32	0:00:11
	P2	9:24:32	9:25:00	0:00:28
	P3	9:25:00	9:25:18	0:00:18
	P4	9:25:18	9:25:48	0:00:30
	P3	9:25:48	9:25:53	0:00:05
	P4	9:25:53	9:25:59	0:00:06
	P3	9:25:59	9:26:04	0:00:05
	P4	9:26:04	9:26:19	0:00:15
	P3	9:26:19	9:26:42	0:00:23
	P4	9:26:42	9:26:50	0:00:08
	P3	9:26:50	9:27:00	0:00:10

Cycle	Phase	Start Time	End Time	Duration
	P4	9:27:00	9:27:08	0:00:08
	P3	9:27:08	9:27:16	0:00:08
	P4	9:27:16	9:27:21	0:00:05
	P3	9:27:21	9:27:27	0:00:06
	P4	9:27:27	9:27:36	0:00:09
	P3	9:27:36	9:27:54	0:00:18
	P4	9:27:54	9:28:08	0:00:14
	P3	9:28:08	9:28:24	0:00:16
	P4	9:28:24	9:28:40	0:00:16
	P3	9:28:40	9:28:58	0:00:18
	P4	9:28:58	9:29:11	0:00:13
	P5	9:29:11	9:31:15	0:02:04
3	P2	9:31:15	9:31:58	0:00:43
	P1	9:31:58	9:32:19	0:00:21
	P2	9:32:19	9:32:51	0:00:32
	P1	9:32:51	9:33:51	0:01:00
	P2	9:33:51	9:34:24	0:00:33
	P1	9:34:24	9:34:33	0:00:09
	P2	9:34:33	9:34:43	0:00:10
	P1	9:34:43	9:34:51	0:00:08
	P2	9:34:51	9:35:11	0:00:20
	P1	9:35:11	9:35:18	0:00:07
	P2	9:35:18	9:35:28	0:00:10
	P1	9:35:28	9:35:35	0:00:07
	P2	9:35:35	9:35:47	0:00:12
	P3	9:35:47	9:36:09	0:00:22
	P4	9:36:09	9:36:20	0:00:11

Cycle	Phase	Start Time	End Time	Duration
	P3	9:36:20	9:36:32	0:00:12
	P4	9:36:32	9:36:58	0:00:26
	P3	9:36:58	9:37:06	0:00:08
	P4	9:37:06	9:37:31	0:00:25
	P3	9:37:31	9:37:38	0:00:07
	P4	9:37:38	9:37:50	0:00:12
	P3	9:37:50	9:38:02	0:00:12
	P4	9:38:02	9:38:07	0:00:05
	P3	9:38:07	9:38:31	0:00:24
	P4	9:38:31	9:38:35	0:00:04
	P3	9:38:35	9:38:40	0:00:05
	P4	9:38:40	9:38:45	0:00:05
	P5	9:38:45	9:40:53	0:02:08
4	P1	9:40:53	9:41:04	0:00:11
	P2	9:41:04	9:41:54	0:00:50
	P1	9:41:54	9:42:06	0:00:12
	P2	9:42:06	9:42:18	0:00:12
	P1	9:42:18	9:42:34	0:00:16
	P2	9:42:34	9:42:48	0:00:14
	P1	9:42:48	9:43:03	0:00:15
	P2	9:43:03	9:43:12	0:00:09
	P1	9:43:12	9:43:23	0:00:11
	P2	9:43:23	9:43:43	0:00:20
	P1	9:43:43	9:43:52	0:00:09
	P2	9:43:52	9:44:07	0:00:15
	P1	9:44:07	9:44:20	0:00:13
	P3	9:44:20	9:45:12	0:00:52

Cycle	Phase	Start Time	End Time	Duration
	P4	9:45:12	9:45:19	0:00:07
	P3	9:45:19	9:45:26	0:00:07
	P4	9:45:26	9:45:31	0:00:05
	P3	9:45:31	9:45:37	0:00:06
	P4	9:45:37	9:45:42	0:00:05
	P3	9:45:42	9:46:06	0:00:24
	P4	9:46:06	9:46:12	0:00:06
	P3	9:46:12	9:46:21	0:00:09
	P4	9:46:21	9:46:35	0:00:14
	P3	9:46:35	9:46:38	0:00:03
	P5	9:46:38	9:49:02	0:02:24
5	P2	9:49:02	9:49:16	0:00:14
	P1	9:49:16	9:49:41	0:00:25
	P2	9:49:41	9:50:20	0:00:39
	P1	9:50:20	9:50:39	0:00:19
	P2	9:50:39	9:51:07	0:00:28
	P1	9:51:07	9:51:20	0:00:13
	P2	9:51:20	9:51:44	0:00:24
	P1	9:51:44	9:51:58	0:00:14
	P2	9:51:58	9:52:10	0:00:12
	P3	9:52:10	9:52:27	0:00:17
	P4	9:52:27	9:52:50	0:00:23
	P3	9:52:50	9:53:09	0:00:19
	P4	9:53:09	9:53:31	0:00:22
	P3	9:53:31	9:53:57	0:00:26
	P4	9:53:57	9:54:03	0:00:06
	P3	9:54:03	9:54:14	0:00:11

Cycle	Phase	Start Time	End Time	Duration
	P5	9:54:14	9:56:25	0:02:11
6	P2	9:56:25	9:56:44	0:00:19
	P1	9:56:44	9:57:03	0:00:19
	P2	9:57:03	9:57:38	0:00:35
	P1	9:57:38	9:57:46	0:00:08
	P2	9:57:46	9:58:21	0:00:35
	P1	9:58:21	9:58:38	0:00:17
	P4	9:58:38	9:59:01	0:00:23
	P3	9:59:01	9:59:39	0:00:38
	P4	9:59:39	9:59:51	0:00:12
	P3	9:59:51	9:59:58	0:00:07
	P4	9:59:58	10:00:00	0:00:02
	P5	10:00:00	10:01:55	0:01:55
7	P1	10:01:55	10:02:04	0:00:09
	P2	10:02:04	10:02:34	0:00:30
	P1	10:02:34	10:02:47	0:00:13
	P2	10:02:47	10:03:11	0:00:24
	P1	10:03:11	10:03:25	0:00:14
	P2	10:03:25	10:03:41	0:00:16
	P1	10:03:41	10:04:06	0:00:25
	P2	10:04:06	10:04:19	0:00:13
	P1	10:04:19	10:04:28	0:00:09
	P2	10:04:28	10:04:37	0:00:09
	P1	10:04:37	10:04:45	0:00:08
	P2	10:04:45	10:04:55	0:00:10
	P4	10:04:55	10:05:09	0:00:14
	P3	10:05:09	10:05:20	0:00:11

Cycle	Phase	Start Time	End Time	Duration
	P4	10:05:20	10:05:33	0:00:13
	P3	10:05:33	10:05:40	0:00:07
	P4	10:05:40	10:05:51	0:00:11
	P3	10:05:51	10:06:07	0:00:16
	P4	10:06:07	10:06:12	0:00:05
	P3	10:06:12	10:06:20	0:00:08
	P5	10:06:20	10:07:36	0:01:16
8	P1	10:07:36	10:08:05	0:00:29
	P2	10:08:05	10:08:47	0:00:42
	P1	10:08:47	10:09:09	0:00:22

Cycle	Phase	Start Time	End Time	Duration
	P2	10:09:09	10:09:27	0:00:18
	P1	10:09:27	10:09:39	0:00:12
	P2	10:09:39	10:10:14	0:00:35
	P1	10:10:14	10:10:28	0:00:14
	P2	10:10:28	10:10:33	0:00:05
	P3	10:10:33	10:10:59	0:00:26
	P4	10:10:59	10:11:08	0:00:09
	P3	10:11:08	10:11:25	0:00:17
	P5	10:11:25	10:13:16	0:01:51

Appendix C.2: Phasing and Timing Observations for Day-2

Cycle	Phase	Start Time	End Time	Duration
1	P2	9:02:10	9:02:35	0:00:25
	P1	9:02:35	9:02:46	0:00:11
	P2	9:02:46	9:03:10	0:00:24
	P1	9:03:10	9:03:26	0:00:16
	P2	9:03:26	9:03:43	0:00:17
	P1	9:03:43	9:03:55	0:00:12
	P2	9:03:55	9:04:02	0:00:07
	P1	9:04:02	9:04:14	0:00:12
	P2	9:04:14	9:04:31	0:00:17
	P4	9:04:31	9:04:39	0:00:08
	P3	9:04:39	9:04:59	0:00:20
	P4	9:04:59	9:05:10	0:00:11
	P3	9:05:10	9:05:19	0:00:09
	P4	9:05:19	9:05:26	0:00:07
	P5	9:05:26	9:06:39	0:01:13
2	P2	9:06:39	9:07:15	0:00:36
	P1	9:07:15	9:07:23	0:00:08
	P2	9:07:23	9:07:30	0:00:07
	P1	9:07:30	9:07:34	0:00:04
	P2	9:07:34	9:08:01	0:00:27
	P1	9:08:01	9:08:10	0:00:09
	P2	9:08:10	9:08:21	0:00:11
	P1	9:08:21	9:08:29	0:00:08
	P2	9:08:29	9:08:40	0:00:11
	P1	9:08:40	9:08:46	0:00:06

Cycle	Phase	Start Time	End Time	Duration
	P2	9:08:46	9:08:57	0:00:11
	P1	9:08:57	9:09:06	0:00:09
	P2	9:09:06	9:09:22	0:00:16
	P1	9:09:22	9:09:27	0:00:05
	P2	9:09:27	9:09:38	0:00:11
	P4	9:09:38	9:09:42	0:00:04
	P3	9:09:42	9:09:55	0:00:13
	P4	9:09:55	9:10:15	0:00:20
	P3	9:10:15	9:10:51	0:00:36
	P4	9:10:51	9:11:02	0:00:11
	P3	9:11:02	9:11:13	0:00:11
	P5	9:11:13	9:12:57	0:01:44
3	P2	9:12:57	9:13:06	0:00:09
	P1	9:13:06	9:13:32	0:00:26
	P2	9:13:32	9:13:52	0:00:20
	P1	9:13:52	9:14:04	0:00:12
	P2	9:14:04	9:14:42	0:00:38
	P1	9:14:42	9:14:59	0:00:17
	P2	9:14:59	9:15:29	0:00:30
	P1	9:15:29	9:15:34	0:00:05
	P3	9:15:34	9:16:00	0:00:26
	P4	9:16:00	9:16:26	0:00:26
	P3	9:16:26	9:16:32	0:00:06
	P4	9:16:32	9:16:35	0:00:03
	P3	9:16:35	9:16:42	0:00:07

Cycle	Phase	Start Time	End Time	Duration
	P4	9:16:42	9:16:50	0:00:08
	P3	9:16:50	9:17:05	0:00:15
	P4	9:17:05	9:17:14	0:00:09
	P5	9:17:14	9:18:35	0:01:21
4	P2	9:18:35	9:18:43	0:00:08
	P1	9:18:43	9:18:49	0:00:06
	P2	9:18:49	9:19:16	0:00:27
	P1	9:19:16	9:19:16	0:00:00
	P2	9:19:16	9:19:22	0:00:06
	P1	9:19:22	9:19:37	0:00:15
	P2	9:19:37	9:19:58	0:00:21
	P1	9:19:58	9:20:02	0:00:04
	P2	9:20:02	9:20:19	0:00:17
	P1	9:20:19	9:20:28	0:00:09
	P2	9:20:28	9:20:46	0:00:18
	P4	9:20:46	9:20:53	0:00:07
	P3	9:20:53	9:21:10	0:00:17
	P4	9:21:10	9:21:27	0:00:17
	P3	9:21:27	9:21:47	0:00:20
	P4	9:21:47	9:22:04	0:00:17
	P3	9:22:04	9:22:22	0:00:18
	P5	9:22:22	9:24:14	0:01:52
5	P2	9:24:14	9:24:18	0:00:04
	P1	9:24:18	9:24:26	0:00:08
	P2	9:24:26	9:24:48	0:00:22
	P1	9:24:48	9:25:03	0:00:15
	P2	9:25:03	9:25:22	0:00:19

Cycle	Phase	Start Time	End Time	Duration
	P1	9:25:22	9:25:30	0:00:08
	P2	9:25:30	9:25:54	0:00:24
	P1	9:25:54	9:26:06	0:00:12
	P2	9:26:06	9:26:17	0:00:11
	P1	9:26:17	9:26:22	0:00:05
	P2	9:26:22	9:26:28	0:00:06
	P1	9:26:28	9:26:40	0:00:12
	P2	9:26:40	9:26:55	0:00:15
	P1	9:26:55	9:27:06	0:00:11
	P2	9:27:06	9:27:40	0:00:34
	P4	9:27:40	9:28:10	0:00:30
	P3	9:28:10	9:28:33	0:00:23
	P4	9:28:33	9:28:46	0:00:13
	P3	9:28:46	9:29:12	0:00:26
	P4	9:29:12	9:29:29	0:00:17
	P3	9:29:29	9:29:34	0:00:05
	P4	9:29:34	9:29:55	0:00:21
	P5	9:29:55	9:31:36	0:01:41
6	P2	9:31:36	9:31:45	0:00:09
	P1	9:31:45	9:31:58	0:00:13
	P2	9:31:58	9:32:33	0:00:35
	P1	9:32:33	9:33:05	0:00:32
	P2	9:33:05	9:33:14	0:00:09
	P1	9:33:14	9:33:22	0:00:08
	P2	9:33:22	9:33:32	0:00:10
	P1	9:33:32	9:34:01	0:00:29
	P2	9:34:01	9:34:51	0:00:50

Cycle	Phase	Start Time	End Time	Duration
	P1	9:34:51	9:35:04	0:00:13
	P4	9:35:04	9:35:20	0:00:16
	P3	9:35:20	9:35:33	0:00:13
	P4	9:35:33	9:35:44	0:00:11
	P3	9:35:44	9:35:56	0:00:12
	P4	9:35:56	9:36:00	0:00:04
	P3	9:36:00	9:36:21	0:00:21
	P4	9:36:21	9:36:34	0:00:13
	P3	9:36:34	9:36:38	0:00:04
	P4	9:36:38	9:36:41	0:00:03
	P3	9:36:41	9:36:46	0:00:05
	P4	9:36:46	9:36:55	0:00:09
	P3	9:36:55	9:37:08	0:00:13
	P4	9:37:08	9:37:13	0:00:05
	P5	9:37:13	9:39:06	0:01:53
7	P1	9:39:06	9:39:22	0:00:16
	P2	9:39:22	9:40:06	0:00:44
	P1	9:40:06	9:40:28	0:00:22
	P2	9:40:28	9:40:35	0:00:07
	P1	9:40:35	9:40:56	0:00:21
	P2	9:40:56	9:41:18	0:00:22
	P1	9:41:18	9:41:53	0:00:35
	P2	9:41:53	9:42:39	0:00:46
	P1	9:42:39	9:42:43	0:00:04
	P2	9:42:43	9:43:08	0:00:25
	P1	9:43:08	9:43:18	0:00:10
	P2	9:43:18	9:43:26	0:00:08

Cycle	Phase	Start Time	End Time	Duration
	P1	9:43:26	9:43:41	0:00:15
	P2	9:43:41	9:44:17	0:00:36
	P4	9:44:17	9:44:40	0:00:23
	P3	9:44:40	9:44:59	0:00:19
	P4	9:44:59	9:45:16	0:00:17
	P3	9:45:16	9:45:22	0:00:06
	P4	9:45:22	9:45:30	0:00:08
	P3	9:45:30	9:45:37	0:00:07
	P4	9:45:37	9:45:41	0:00:04
	P3	9:45:41	9:45:47	0:00:06
	P4	9:45:47	9:45:51	0:00:04
	P3	9:45:51	9:45:55	0:00:04
	P4	9:45:55	9:45:58	0:00:03
	P3	9:45:58	9:46:29	0:00:31
	P4	9:46:29	9:46:47	0:00:18
	P3	9:46:47	9:47:00	0:00:13
	P4	9:47:00	9:47:04	0:00:04
	P5	9:47:04	9:48:38	0:01:34
8	P2	9:48:38	9:48:48	0:00:10
	P1	9:48:48	9:48:53	0:00:05
	P2	9:48:53	9:49:23	0:00:30
	P1	9:49:23	9:49:35	0:00:12
	P2	9:49:35	9:49:52	0:00:17
	P1	9:49:52	9:49:56	0:00:04
	P2	9:49:56	9:50:09	0:00:13
	P1	9:50:09	9:50:13	0:00:04
	P2	9:50:13	9:50:18	0:00:05

Cycle	Phase	Start Time	End Time	Duration
	P1	9:50:18	9:50:30	0:00:12
	P2	9:50:30	9:50:36	0:00:06
	P4	9:50:36	9:50:43	0:00:07
	P3	9:50:43	9:51:04	0:00:21
	P4	9:51:04	9:51:09	0:00:05
	P3	9:51:09	9:51:54	0:00:45
	P4	9:51:54	9:52:02	0:00:08
	P5	9:52:02	9:53:25	0:01:23
9	P1	9:53:25	9:53:26	0:00:01
	P2	9:53:26	9:53:52	0:00:26
	P1	9:53:52	9:54:10	0:00:18
	P2	9:54:10	9:54:19	0:00:09

Cycle	Phase	Start Time	End Time	Duration
	P1	9:54:19	9:54:24	0:00:05
	P2	9:54:24	9:54:33	0:00:09
	P1	9:54:33	9:54:44	0:00:11
	P2	9:54:44	9:55:08	0:00:24
	P1	9:55:08	9:55:14	0:00:06
	P4	9:55:14	9:55:26	0:00:12
	P3	9:55:26	9:55:46	0:00:20
	P4	9:55:46	9:55:56	0:00:10
	P3	9:55:56	9:56:22	0:00:26
	P4	9:56:22	9:56:30	0:00:08
	P5	9:56:30	9:59:15	0:02:45

Appendix C.3: Phasing and Timing Observations for Day-3

Cycle	Phase	Start Time	End Time	Duration
1	P2	9:30:27	9:30:41	0:00:14
	P1	9:30:41	9:30:50	0:00:09
	P2	9:30:50	9:31:08	0:00:18
	P1	9:31:08	9:31:26	0:00:18
	P2	9:31:26	9:31:54	0:00:28
	P1	9:31:54	9:32:06	0:00:12
	P2	9:32:06	9:32:13	0:00:07
	P1	9:32:13	9:32:24	0:00:11
	P2	9:32:24	9:32:34	0:00:10
	P1	9:32:34	9:32:41	0:00:07
	P2	9:32:41	9:32:58	0:00:17
	P1	9:32:58	9:33:16	0:00:18
	P2	9:33:16	9:33:44	0:00:28
	P1	9:33:44	9:33:49	0:00:05
	P2	9:33:49	9:34:18	0:00:29
	P1	9:34:18	9:34:30	0:00:12
	P2	9:34:30	9:34:45	0:00:15
	P1	9:34:45	9:34:57	0:00:12
	P4	9:34:57	9:35:11	0:00:14
	P3	9:35:11	9:35:23	0:00:12
	P4	9:35:23	9:35:42	0:00:19
	P3	9:35:42	9:35:50	0:00:08
	P4	9:35:50	9:36:07	0:00:17
	P3	9:36:07	9:36:23	0:00:16
	P4	9:36:23	9:36:47	0:00:24

Cycle	Phase	Start Time	End Time	Duration
	P3	9:36:47	9:36:58	0:00:11
	P4	9:36:58	9:37:07	0:00:09
	P3	9:37:07	9:37:12	0:00:05
	P4	9:37:12	9:37:28	0:00:16
	P5	9:37:28	9:39:25	0:01:57
2	P1	9:39:25	9:39:41	0:00:16
	P2	9:39:41	9:40:07	0:00:26
	P1	9:40:07	9:40:19	0:00:12
	P2	9:40:19	9:40:45	0:00:26
	P1	9:40:45	9:41:03	0:00:18
	P2	9:41:03	9:41:25	0:00:22
	P1	9:41:25	9:41:34	0:00:09
	P2	9:41:34	9:42:17	0:00:43
	P1	9:42:17	9:42:27	0:00:10
	P2	9:42:27	9:42:59	0:00:32
	P1	9:42:59	9:43:09	0:00:10
	P2	9:43:09	9:43:51	0:00:42
	P4	9:43:51	9:44:09	0:00:18
	P3	9:44:09	9:44:23	0:00:14
	P4	9:44:23	9:44:54	0:00:31
	P3	9:44:54	9:45:11	0:00:17
	P4	9:45:11	9:45:35	0:00:24
	P3	9:45:35	9:45:48	0:00:13
	P4	9:45:48	9:46:25	0:00:37
	P5	9:46:25	9:48:45	0:02:20

Cycle	Phase	Start Time	End Time	Duration
3	P2	9:48:45	9:49:34	0:00:49
	P1	9:49:34	9:49:59	0:00:25
	P2	9:49:59	9:50:37	0:00:38
	P1	9:50:37	9:51:28	0:00:51
	P2	9:51:28	9:51:59	0:00:31
	P1	9:51:59	9:52:17	0:00:18
	P2	9:52:17	9:52:29	0:00:12
	P1	9:52:29	9:52:37	0:00:08
	P2	9:52:37	9:53:18	0:00:41
	P1	9:53:18	9:53:26	0:00:08
	P3	9:53:26	9:53:44	0:00:18
	P4	9:53:44	9:54:04	0:00:20
	P3	9:54:04	9:54:11	0:00:07
	P4	9:54:11	9:54:25	0:00:14
	P3	9:54:25	9:54:31	0:00:06
	P4	9:54:31	9:54:42	0:00:11
	P3	9:54:42	9:54:52	0:00:10
	P4	9:54:52	9:55:01	0:00:09
	P3	9:55:01	9:55:20	0:00:19
	P4	9:55:20	9:55:43	0:00:23
	P3	9:55:43	9:55:52	0:00:09
	P4	9:55:52	9:56:02	0:00:10
	P5	9:56:02	9:58:34	0:02:32
4	P1	9:58:34	9:58:51	0:00:17
	P2	9:58:51	9:59:29	0:00:38
	P1	9:59:29	9:59:44	0:00:15
	P2	9:59:44	10:00:12	0:00:28

Cycle	Phase	Start Time	End Time	Duration
	P1	10:00:12	10:00:25	0:00:13
	P2	10:00:25	10:00:50	0:00:25
	P1	10:00:50	10:01:10	0:00:20
	P2	10:01:10	10:01:36	0:00:26
	P1	10:01:36	10:01:51	0:00:15
	P2	10:01:51	10:02:13	0:00:22
	P1	10:02:13	10:02:24	0:00:11
	P3	10:02:24	10:02:54	0:00:30
	P4	10:02:54	10:03:12	0:00:18
	P3	10:03:12	10:03:29	0:00:17
	P4	10:03:29	10:03:38	0:00:09
	P3	10:03:38	10:03:49	0:00:11
	P4	10:03:49	10:04:19	0:00:30
	P3	10:04:19	10:04:46	0:00:27
	P5	10:04:46	10:07:18	0:02:32
5	P2	10:07:18	10:07:39	0:00:21
	P1	10:07:39	10:07:47	0:00:08
	P2	10:07:47	10:08:03	0:00:16
	P1	10:08:03	10:08:10	0:00:07
	P2	10:08:10	10:08:33	0:00:23
	P1	10:08:33	10:08:41	0:00:08
	P2	10:08:41	10:08:57	0:00:16
	P1	10:08:57	10:09:06	0:00:09
	P2	10:09:06	10:09:25	0:00:19
	P1	10:09:25	10:09:36	0:00:11
	P2	10:09:36	10:09:47	0:00:11
	P1	10:09:47	10:10:05	0:00:18

Cycle	Phase	Start Time	End Time	Duration
	P2	10:10:05	10:10:23	0:00:18
	P1	10:10:23	10:10:29	0:00:06
	P2	10:10:29	10:10:48	0:00:19
	P1	10:10:48	10:10:58	0:00:10
	P2	10:10:58	10:11:07	0:00:09
	P1	10:11:07	10:11:28	0:00:21
	P4	10:11:28	10:11:40	0:00:12
	P3	10:11:40	10:12:02	0:00:22
	P4	10:12:02	10:12:14	0:00:12
	P3	10:12:14	10:12:27	0:00:13
	P4	10:12:27	10:12:49	0:00:22
	P3	10:12:49	10:13:05	0:00:16
	P4	10:13:05	10:13:29	0:00:24
	P3	10:13:29	10:13:41	0:00:12
	P5	10:13:41	10:15:29	0:01:48
	P2	10:15:29	10:15:59	0:00:30
	P1	10:15:59	10:16:12	0:00:13
	P2	10:16:12	10:16:40	0:00:28
	P1	10:16:40	10:16:55	0:00:15
6	P2	10:16:55	10:17:04	0:00:09
	P1	10:17:04	10:17:17	0:00:13
	P2	10:17:17	10:17:31	0:00:14
	P1	10:17:31	10:17:39	0:00:08
	P2	10:17:39	10:18:07	0:00:28

Cycle	Phase	Start Time	End Time	Duration
	P1	10:18:07	10:18:18	0:00:11
	P2	10:18:18	10:18:49	0:00:31
	P4	10:18:49	10:19:04	0:00:15
	P3	10:19:04	10:19:22	0:00:18
	P4	10:19:22	10:20:00	0:00:38
	P3	10:20:00	10:20:03	0:00:03
	P5	10:20:03	10:22:54	0:02:51
	P2	10:22:54	10:23:39	0:00:45
	P1	10:23:39	10:23:50	0:00:11
	P2	10:23:50	10:24:14	0:00:24
	P1	10:24:14	10:24:25	0:00:11
	P2	10:24:25	10:24:51	0:00:26
	P1	10:24:51	10:24:59	0:00:08
	P2	10:24:59	10:25:20	0:00:21
	P1	10:25:20	10:25:30	0:00:10
7	P2	10:25:30	10:25:57	0:00:27
	P1	10:25:57	10:26:03	0:00:06
	P2	10:26:03	10:26:18	0:00:15
	P4	10:26:18	10:26:36	0:00:18
	P3	10:26:36	10:27:06	0:00:30
	P4	10:27:06	10:27:24	0:00:18
	P3	10:27:24	10:27:31	0:00:07
	P4	10:27:31	10:27:58	0:00:27
	P5	10:27:58	10:30:15	0:02:17

Appendix C.4: Phasing and Timing Observations for Day-4

Cycle	Phase	Start Time	End Time	Duration
1	P2	9:59:49	9:59:57	0:00:08
	P1	9:59:57	10:00:11	0:00:14
	P2	10:00:11	10:00:22	0:00:11
	P3	10:00:22	10:00:39	0:00:17
	P4	10:00:39	10:00:47	0:00:08
	P5	10:00:47	10:01:07	0:00:20
2	P2	10:01:07	10:01:32	0:00:25
	P4	10:01:32	10:01:59	0:00:27
	P5	10:01:59	10:02:16	0:00:17
	P2	10:02:16	10:02:37	0:00:21
	P4	10:02:37	10:03:01	0:00:24
	P5	10:03:01	10:03:17	0:00:16
3	P2	10:03:17	10:03:46	0:00:29
	P3	10:03:46	10:03:54	0:00:08
	P4	10:03:54	10:04:16	0:00:22
	P5	10:04:16	10:04:38	0:00:22
	P2	10:04:38	10:05:22	0:00:44
	P3	10:05:22	10:05:30	0:00:08
	P4	10:05:30	10:05:43	0:00:13
	P2	10:05:43	10:06:03	0:00:20
	P5	10:06:03	10:06:45	0:00:42
4	P2	10:06:45	10:07:07	0:00:22
	P3	10:07:07	10:07:21	0:00:14
	P4	10:07:21	10:07:31	0:00:10
	P5	10:07:31	10:07:50	0:00:19
5	P1	10:07:50	10:07:58	0:00:08
	P2	10:07:58	10:08:20	0:00:22

Cycle	Phase	Start Time	End Time	Duration
	P4	10:08:20	10:08:34	0:00:14
	P5	10:08:34	10:08:47	0:00:13
6	P2	10:08:47	10:09:15	0:00:28
	P3	10:09:15	10:09:23	0:00:08
	P4	10:09:23	10:09:28	0:00:05
	P5	10:09:28	10:09:34	0:00:06
7	P2	10:09:34	10:09:43	0:00:09
	P1	10:09:43	10:09:49	0:00:06
	P3	10:09:49	10:09:58	0:00:09
	P5	10:09:58	10:10:04	0:00:06
8	P1	10:10:04	10:10:16	0:00:12
	P2	10:10:16	10:10:22	0:00:06
	P3	10:10:22	10:10:32	0:00:10
	P5	10:10:32	10:10:42	0:00:10
9	P2	10:10:42	10:11:08	0:00:26
	P3	10:11:08	10:11:40	0:00:32
	P5	10:11:40	10:12:14	0:00:34
10	P1	10:12:14	10:12:25	0:00:11
	P2	10:12:25	10:12:47	0:00:22
	P3	10:12:47	10:13:06	0:00:19
	P4	10:13:06	10:13:18	0:00:12
	P5	10:13:18	10:13:41	0:00:23
11	P2	10:13:41	10:13:59	0:00:18
	P1	10:13:59	10:14:11	0:00:12
	P3	10:14:11	10:14:56	0:00:45
	P5	10:14:56	10:15:23	0:00:27
12	P1	10:15:23	10:15:38	0:00:15

Cycle	Phase	Start Time	End Time	Duration
	P2	10:15:38	10:15:50	0:00:12
	P1	10:15:50	10:16:15	0:00:25
	P3	10:16:15	10:16:32	0:00:17
	P5	10:16:32	10:17:14	0:00:42
13	P2	10:17:14	10:17:43	0:00:29
	P1	10:17:43	10:17:50	0:00:07
	P2	10:17:50	10:18:06	0:00:16
	P3	10:18:06	10:18:21	0:00:15
	P4	10:18:21	10:18:43	0:00:22
	P5	10:18:43	10:19:26	0:00:43
14	P1	10:19:26	10:19:42	0:00:16
	P2	10:19:42	10:20:10	0:00:28
	P3	10:20:10	10:20:35	0:00:25
	P4	10:20:35	10:20:58	0:00:23
	P5	10:20:58	10:21:20	0:00:22
15	P1	10:21:20	10:21:31	0:00:11
	P2	10:21:31	10:22:01	0:00:30
	P3	10:22:01	10:22:19	0:00:18
	P4	10:22:19	10:22:32	0:00:13
	P5	10:22:32	10:22:51	0:00:19
16	P1	10:22:51	10:23:00	0:00:09
	P2	10:23:00	10:23:14	0:00:14
	P3	10:23:14	10:23:28	0:00:14
	P4	10:23:28	10:23:39	0:00:11
	P5	10:23:39	10:23:52	0:00:13
17	P2	10:23:52	10:24:09	0:00:17
	P1	10:24:09	10:24:23	0:00:14

Cycle	Phase	Start Time	End Time	Duration
	P3	10:24:23	10:24:35	0:00:12
	P4	10:24:35	10:24:45	0:00:10
	P5	10:24:45	10:25:06	0:00:21
18	P1	10:25:06	10:25:19	0:00:13
	P2	10:25:19	10:25:29	0:00:10
	P3	10:25:29	10:25:39	0:00:10
	P4	10:25:39	10:26:00	0:00:21
	P3	10:26:00	10:26:14	0:00:14
	P4	10:26:14	10:26:26	0:00:12
	P5	10:26:26	10:26:52	0:00:26
19	P1	10:26:52	10:27:03	0:00:11
	P2	10:27:03	10:27:15	0:00:12
	P1	10:27:15	10:27:26	0:00:11
	P2	10:27:26	10:27:34	0:00:08
	P3	10:27:34	10:28:02	0:00:28
	P5	10:28:02	10:29:10	0:01:08
20	P2	10:29:10	10:29:39	0:00:29
	P1	10:29:39	10:29:48	0:00:09
	P3	10:29:48	10:30:09	0:00:21
	P4	10:30:09	10:30:18	0:00:09
	P3	10:30:18	10:30:27	0:00:09
	P5	10:30:27	10:31:05	0:00:38
21	P2	10:31:05	10:31:17	0:00:12
	P1	10:31:17	10:31:26	0:00:09
	P2	10:31:26	10:31:39	0:00:13
	P3	10:31:39	10:31:54	0:00:15
	P4	10:31:54	10:32:09	0:00:15

Cycle	Phase	Start Time	End Time	Duration
	P5	10:32:09	10:32:56	0:00:47
22	P2	10:32:56	10:33:08	0:00:12
	P1	10:33:08	10:33:16	0:00:08
	P2	10:33:16	10:33:36	0:00:20
	P3	10:33:36	10:34:05	0:00:29
	P4	10:34:05	10:34:19	0:00:14
	P5	10:34:19	10:34:34	0:00:15
23	P2	10:34:34	10:35:09	0:00:35
	P1	10:35:09	10:35:13	0:00:04
	P3	10:35:13	10:35:41	0:00:28
	P5	10:35:41	10:36:13	0:00:32
24	P2	10:36:13	10:36:47	0:00:34
	P4	10:36:47	10:36:53	0:00:06
	P3	10:36:53	10:37:01	0:00:08
	P4	10:37:01	10:37:22	0:00:21
	P5	10:37:22	10:37:38	0:00:16
25	P2	10:37:38	10:37:46	0:00:08
	P1	10:37:46	10:37:52	0:00:06
	P2	10:37:52	10:38:07	0:00:15
	P3	10:38:07	10:38:34	0:00:27
	P5	10:38:34	10:38:50	0:00:16
26	P2	10:38:50	10:39:10	0:00:20
	P1	10:39:10	10:39:17	0:00:07
	P3	10:39:17	10:39:29	0:00:12
	P4	10:39:29	10:39:55	0:00:26
	P5	10:39:55	10:40:32	0:00:37
27	P2	10:40:32	10:40:45	0:00:13

Cycle	Phase	Start Time	End Time	Duration
	P1	10:40:45	10:40:50	0:00:05
	P2	10:40:50	10:41:21	0:00:31
	P3	10:41:21	10:41:36	0:00:15
	P4	10:41:36	10:41:58	0:00:22
	P5	10:41:58	10:42:27	0:00:29
28	P1	10:42:27	10:42:43	0:00:16
	P2	10:42:43	10:43:00	0:00:17
	P4	10:43:00	10:43:10	0:00:10
	P3	10:43:10	10:43:25	0:00:15
	P5	10:43:25	10:44:07	0:00:42
29	P2	10:44:07	10:44:31	0:00:24
	P3	10:44:31	10:44:39	0:00:08
	P4	10:44:39	10:45:06	0:00:27
	P5	10:45:06	10:45:31	0:00:25
30	P2	10:45:31	10:45:36	0:00:05
	P1	10:45:36	10:45:42	0:00:06
	P2	10:45:42	10:45:57	0:00:15
	P4	10:45:57	10:46:21	0:00:24
	P5	10:46:21	10:46:46	0:00:25
31	P2	10:46:46	10:47:03	0:00:17
	P1	10:47:03	10:47:09	0:00:06
	P2	10:47:09	10:47:19	0:00:10
	P3	10:47:19	10:47:32	0:00:13
	P4	10:47:32	10:47:54	0:00:22
	P5	10:47:54	10:48:54	0:01:00
32	P2	10:48:54	10:49:06	0:00:12
	P1	10:49:06	10:49:13	0:00:07

Cycle	Phase	Start Time	End Time	Duration
	P2	10:49:13	10:49:32	0:00:19
	P3	10:49:32	10:49:48	0:00:16
	P4	10:49:48	10:50:01	0:00:13
	P5	10:50:01	10:50:17	0:00:16
33	P2	10:50:17	10:50:55	0:00:38
	P3	10:50:55	10:51:11	0:00:16
	P5	10:51:11	10:51:35	0:00:24
34	P1	10:51:35	10:51:43	0:00:08
	P2	10:51:43	10:52:08	0:00:25
	P3	10:52:08	10:52:42	0:00:34
	P5	10:52:42	10:53:08	0:00:26
35	P1	10:53:08	10:53:18	0:00:10
	P2	10:53:18	10:53:41	0:00:23
	P3	10:53:41	10:54:06	0:00:25
	P5	10:54:06	10:54:30	0:00:24
36	P2	10:54:30	10:54:43	0:00:13
	P1	10:54:43	10:55:06	0:00:23
	P3	10:55:06	10:55:21	0:00:15
	P4	10:55:21	10:55:31	0:00:10
	P5	10:55:31	10:55:59	0:00:28

Cycle	Phase	Start Time	End Time	Duration
37	P2	10:55:59	10:56:17	0:00:18
	P1	10:56:17	10:56:27	0:00:10
	P2	10:56:27	10:56:33	0:00:06
	P3	10:56:33	10:56:41	0:00:08
	P4	10:56:41	10:56:54	0:00:13
	P5	10:56:54	10:57:16	0:00:22
38	P2	10:57:16	10:57:24	0:00:08
	P1	10:57:24	10:57:28	0:00:04
	P2	10:57:28	10:57:43	0:00:15
	P3	10:57:43	10:57:57	0:00:14
	P4	10:57:57	10:58:04	0:00:07
	P5	10:58:04	10:58:26	0:00:22
39	P2	10:58:26	10:58:35	0:00:09
	P1	10:58:35	10:58:50	0:00:15
	P3	10:58:50	10:59:04	0:00:14
	P5	10:59:04	10:59:18	0:00:14
40	P2	10:59:18	10:59:32	0:00:14
	P3	10:59:32	10:59:40	0:00:08
	P4	10:59:40	10:59:51	0:00:11
	P5	10:59:51	11:00:07	0:00:16

Appendix C.5: Phasing and Timing Observations for Day-5

Cycle	Phase	Start Time	End Time	Duration
1	P5	9:30:19	9:30:49	0:00:30
	P2	9:30:49	9:31:07	0:00:18
	P1	9:31:07	9:31:31	0:00:24
	P3	9:31:31	9:31:42	0:00:11
	P4	9:31:42	9:31:49	0:00:07
	P3	9:31:49	9:31:53	0:00:04
	P4	9:31:53	9:32:02	0:00:09
	P3	9:32:02	9:32:18	0:00:16
2	P5	9:32:18	9:32:49	0:00:31
	P2	9:32:49	9:33:11	0:00:22
	P1	9:33:11	9:33:17	0:00:06
	P2	9:33:17	9:33:24	0:00:07
	P3	9:33:24	9:33:37	0:00:13
	P4	9:33:37	9:33:49	0:00:12
	P3	9:33:49	9:34:01	0:00:12
3	P5	9:34:01	9:34:51	0:00:50
	P2	9:34:51	9:35:32	0:00:41
	P1	9:35:32	9:35:45	0:00:13
	P3	9:35:45	9:36:08	0:00:23
	P4	9:36:08	9:36:38	0:00:30
4	P5	9:36:38	9:37:08	0:00:30
	P2	9:37:08	9:37:31	0:00:23
	P1	9:37:31	9:37:40	0:00:09
	P2	9:37:40	9:38:04	0:00:24
	P3	9:38:04	9:39:02	0:00:58

Cycle	Phase	Start Time	End Time	Duration
5	P5	9:39:02	9:40:04	0:01:02
	P2	9:40:04	9:40:10	0:00:06
	P1	9:40:10	9:40:20	0:00:10
	P2	9:40:20	9:40:38	0:00:18
	P1	9:40:38	9:40:49	0:00:11
	P2	9:40:49	9:41:06	0:00:17
	P3	9:41:06	9:41:30	0:00:24
	P4	9:41:30	9:41:44	0:00:14
	P3	9:41:44	9:41:54	0:00:10
	P4	9:41:54	9:42:09	0:00:15
6	P5	9:42:09	9:42:54	0:00:45
	P1	9:42:54	9:43:17	0:00:23
	P2	9:43:17	9:43:31	0:00:14
	P1	9:43:31	9:43:41	0:00:10
	P3	9:43:41	9:44:09	0:00:28
	P4	9:44:09	9:44:17	0:00:08
7	P5	9:44:17	9:45:01	0:00:44
	P1	9:45:01	9:45:14	0:00:13
	P2	9:45:14	9:45:56	0:00:42
	P3	9:45:56	9:46:22	0:00:26
	P4	9:46:22	9:46:34	0:00:12
8	P5	9:46:34	9:47:18	0:00:44
	P1	9:47:18	9:47:34	0:00:16
	P2	9:47:34	9:48:07	0:00:33
	P3	9:48:07	9:48:40	0:00:33

Cycle	Phase	Start Time	End Time	Duration
9	P5	9:48:40	9:49:09	0:00:29
	P1	9:49:09	9:49:25	0:00:16
	P2	9:49:25	9:49:44	0:00:19
	P3	9:49:44	9:50:01	0:00:17
	P4	9:50:01	9:50:14	0:00:13
10	P5	9:50:14	9:50:31	0:00:17
	P2	9:50:31	9:51:16	0:00:45
	P4	9:51:16	9:51:43	0:00:27
11	P5	9:51:43	9:52:06	0:00:23
	P2	9:52:06	9:52:42	0:00:36
	P3	9:52:42	9:53:13	0:00:31
12	P5	9:53:13	9:53:43	0:00:30
	P2	9:53:43	9:53:52	0:00:09
	P1	9:53:52	9:54:00	0:00:08
	P2	9:54:00	9:54:30	0:00:30
	P1	9:54:30	9:54:39	0:00:09
	P3	9:54:39	9:55:00	0:00:21
13	P5	9:55:00	9:55:25	0:00:25
	P1	9:55:25	9:55:41	0:00:16
	P2	9:55:41	9:55:48	0:00:07
	P1	9:55:48	9:55:55	0:00:07
	P2	9:55:55	9:56:01	0:00:06
	P3	9:56:01	9:56:21	0:00:20
14	P5	9:56:21	9:56:50	0:00:29
	P1	9:56:50	9:56:57	0:00:07
	P2	9:56:57	9:57:02	0:00:05
	P1	9:57:02	9:57:07	0:00:05

Cycle	Phase	Start Time	End Time	Duration
	P2	9:57:07	9:57:38	0:00:31
	P1	9:57:38	9:57:45	0:00:07
	P2	9:57:45	9:58:03	0:00:18
	P3	9:58:03	9:58:27	0:00:24
	P4	9:58:27	9:58:42	0:00:15
	P3	9:58:42	9:58:51	0:00:09
	P4	9:58:51	9:59:02	0:00:11
	P3	9:59:02	9:59:12	0:00:10
15	P5	9:59:12	9:59:55	0:00:43
	P2	9:59:55	10:00:32	0:00:37
	P1	10:00:32	10:00:40	0:00:08
	P2	10:00:40	10:00:56	0:00:16
	P3	10:00:56	10:01:30	0:00:34
16	P5	10:01:30	10:02:38	0:01:08
	P2	10:02:38	10:03:00	0:00:22
	P1	10:03:00	10:03:29	0:00:29
	P2	10:03:29	10:03:43	0:00:14
	P3	10:03:43	10:04:12	0:00:29
	P4	10:04:12	10:04:34	0:00:22
17	P5	10:04:34	10:05:28	0:00:54
	P1	10:05:28	10:05:44	0:00:16
	P2	10:05:44	10:05:55	0:00:11
	P1	10:05:55	10:06:07	0:00:12
	P2	10:06:07	10:06:14	0:00:07
	P3	10:06:14	10:06:42	0:00:28
	P4	10:06:42	10:07:10	0:00:28
18	P5	10:07:10	10:07:50	0:00:40

Cycle	Phase	Start Time	End Time	Duration
	P1	10:07:50	10:08:07	0:00:17
	P2	10:08:07	10:08:30	0:00:23
	P3	10:08:30	10:08:47	0:00:17
	P4	10:08:47	10:08:59	0:00:12
	P3	10:08:59	10:09:07	0:00:08
19	P5	10:09:07	10:09:48	0:00:41
	P1	10:09:48	10:10:00	0:00:12
	P2	10:10:00	10:10:13	0:00:13
	P1	10:10:13	10:10:23	0:00:10
	P2	10:10:23	10:10:41	0:00:18
	P3	10:10:41	10:11:07	0:00:26
	P4	10:11:07	10:11:12	0:00:05
20	P5	10:11:12	10:11:49	0:00:37
	P1	10:11:49	10:12:10	0:00:21
	P2	10:12:10	10:12:22	0:00:12
	P1	10:12:22	10:12:32	0:00:10
	P2	10:12:32	10:12:42	0:00:10
	P3	10:12:42	10:13:03	0:00:21
	P4	10:13:03	10:13:10	0:00:07
21	P5	10:13:10	10:13:31	0:00:21
	P1	10:13:31	10:13:46	0:00:15
	P2	10:13:46	10:14:13	0:00:27
	P4	10:14:13	10:14:39	0:00:26
	P3	10:14:39	10:14:57	0:00:18
22	P5	10:14:57	10:15:19	0:00:22
	P2	10:15:19	10:15:27	0:00:08
	P1	10:15:27	10:15:36	0:00:09

Cycle	Phase	Start Time	End Time	Duration
	P2	10:15:36	10:15:56	0:00:20
	P1	10:15:56	10:16:11	0:00:15
	P2	10:16:11	10:16:18	0:00:07
	P3	10:16:18	10:16:40	0:00:22
	P4	10:16:40	10:16:49	0:00:09
23	P5	10:16:49	10:17:14	0:00:25
	P2	10:17:14	10:17:27	0:00:13
	P1	10:17:27	10:17:37	0:00:10
	P2	10:17:37	10:18:17	0:00:40
	P3	10:18:17	10:18:33	0:00:16
	P4	10:18:33	10:18:40	0:00:07
	P3	10:18:40	10:18:52	0:00:12
24	P5	10:18:52	10:19:11	0:00:19
	P1	10:19:11	10:19:27	0:00:16
	P2	10:19:27	10:19:38	0:00:11
	P3	10:19:38	10:19:58	0:00:20
	P4	10:19:58	10:20:07	0:00:09
25	P5	10:20:07	10:21:12	0:01:05
	P2	10:21:12	10:21:22	0:00:10
	P1	10:21:22	10:21:44	0:00:22
	P2	10:21:44	10:22:05	0:00:21
	P3	10:22:05	10:22:19	0:00:14
	P4	10:22:19	10:22:27	0:00:08
	P3	10:22:27	10:22:41	0:00:14
26	P5	10:22:41	10:23:33	0:00:52
	P2	10:23:33	10:24:05	0:00:32
	P1	10:24:05	10:24:13	0:00:08

Cycle	Phase	Start Time	End Time	Duration
	P2	10:24:13	10:24:33	0:00:20
	P3	10:24:33	10:24:56	0:00:23
	P4	10:24:56	10:25:11	0:00:15
	P3	10:25:11	10:25:29	0:00:18
27	P5	10:25:29	10:26:22	0:00:53
	P1	10:26:22	10:26:35	0:00:13
	P2	10:26:35	10:26:51	0:00:16
	P1	10:26:51	10:26:58	0:00:07
	P2	10:26:58	10:27:49	0:00:51

Cycle	Phase	Start Time	End Time	Duration
	P3	10:27:49	10:28:23	0:00:34
	P4	10:28:23	10:28:39	0:00:16
28	P5	10:28:39	10:29:45	0:01:06
	P1	10:29:45	10:29:58	0:00:13
	P2	10:29:58	10:30:16	0:00:18
	P1	10:30:16	10:30:23	0:00:07
	P2	10:30:23	10:30:39	0:00:16
	P3	10:30:39	10:31:04	0:00:25

Appendix D: Back of Queue Observations

Appendix D.1: Back of Queue Observations for Kupondole Leg

Day	Cycle	Recorded At	Length
1	1	9:14:24	349
	2	9:21:47	318
	3	9:31:14	450
	4	9:40:52	342
	5	9:49:01	311
	6	9:56:24	220
	7	10:01:54	298
	8	10:07:35	293
2	1	9:02:09	287
	2	9:06:38	348
	3	9:12:56	312
	4	9:18:34	271
	5	9:24:13	391
	6	9:31:35	394
	7	9:39:05	500
	8	9:48:37	250
3	1	9:30:26	528
	2	9:39:24	521
	3	9:48:44	550
	4	9:58:33	450
	5	10:07:17	489
	6	10:15:28	391

Day	Cycle	Recorded At	Length
	7	10:22:53	399
4	1	9:59:48	70
	2	10:01:06	104
	3	10:03:16	150
	4	10:06:44	63
	5	10:07:49	68
	6	10:08:46	67
	7	10:09:33	59
	8	10:10:03	61
	9	10:10:41	66
	10	10:12:13	70
	11	10:13:40	68
	12	10:15:22	81
	13	10:17:13	81
	14	10:19:25	77
	15	10:21:19	75
	16	10:22:50	64
	17	10:23:51	69
	18	10:26:51	75
	19	10:29:09	73
	20	10:31:04	70

Day	Cycle	Recorded At	Length
	21	10:32:55	74
	22	10:34:33	73
	23	10:36:12	70
	24	10:37:37	67
	25	10:38:49	66
	26	10:40:31	80
	27	10:44:06	64
	28	10:45:30	66
	29	10:46:45	70
	30	10:54:29	72
	31	10:57:15	66
5	1	9:30:48	193
	2	9:32:48	161
	3	9:34:50	248
	4	9:37:07	257
	5	9:40:03	285
	6	9:42:53	216
	7	9:45:00	253
	8	9:47:17	225
	9	9:50:30	207
	10	9:52:05	166

Day	Cycle	Recorded At	Length
	11	9:55:24	166
	12	9:56:49	336
	13	9:59:54	280
	14	10:02:37	299
	15	10:05:27	211

Day	Cycle	Recorded At	Length
	16	10:07:49	184
	17	10:09:47	244
	18	10:15:18	271
	19	10:17:13	290
	20	10:19:10	204

Day	Cycle	Recorded At	Length
	21	10:21:11	244
	22	10:23:32	276
	23	10:26:21	400
	24	10:29:44	248

Appendix D.2: Back of Queue Observations for Maitighar Leg

Day	Cycle	Recorded At	Length
1	1	9:20:05	319
	2	9:29:10	388
	3	9:38:44	400
	4	9:46:37	450
	5	9:54:13	409
	6	9:59:59	359
	7	10:11:24	347
2	1	9:05:25	177
	2	9:11:12	252
	3	9:17:13	196
	4	9:22:21	272
	5	9:29:54	245
	6	9:37:12	274
	7	9:47:03	228
	8	9:52:01	201
	9	9:56:29	400
3	1	9:37:27	410
	2	9:46:24	490
	3	9:56:01	532
	4	10:04:45	532
	5	10:13:40	378
	6	10:20:02	550
	7	10:27:57	480
	8	10:34:02	252

Day	Cycle	Recorded At	Length
4	1	10:00:46	43
	2	10:01:58	82
	3	10:04:15	100
	4	10:07:30	43
	5	10:08:33	39
	6	10:10:31	37
	7	10:11:39	53
	8	10:13:17	45
	9	10:14:55	48
	10	10:16:31	58
	11	10:18:42	59
	12	10:20:57	45
	13	10:22:31	43
	14	10:23:38	39
	15	10:24:44	44
	16	10:26:25	47
	17	10:28:01	76
	18	10:30:26	56
	19	10:32:08	62
	20	10:34:18	40
	21	10:35:40	51
	22	10:37:21	41
	23	10:39:54	55
	24	10:41:57	49

Day	Cycle	Recorded At	Length
	25	10:43:24	58
	26	10:45:05	47
	27	10:46:20	47
	28	10:47:53	70
	29	10:51:10	46
	30	10:52:41	47
	31	10:54:05	46
	32	10:55:30	49
	33	10:58:03	45
	34	10:59:03	39
	35	10:59:50	41
5	1	9:30:18	243
	2	9:32:17	251
	3	9:34:00	404
	4	9:36:37	243
	5	9:39:01	501
	6	9:42:08	364
	7	9:44:16	356
	8	9:46:33	356
	9	9:48:39	235
	10	9:50:13	217
	11	9:51:42	186
	12	9:54:59	202
	13	9:56:20	235

Day	Cycle	Recorded At	Length
	14	9:59:11	348
	15	10:01:29	550
	16	10:04:33	437
	17	10:07:09	324
	18	10:09:06	332

Day	Cycle	Recorded At	Length
	19	10:11:11	299
	20	10:13:09	170
	21	10:14:56	178
	22	10:18:51	154
	23	10:20:06	526

Day	Cycle	Recorded At	Length
	24	10:22:40	421
	25	10:25:28	429
	26	10:28:38	534

Appendix D.3: Back of Queue Observations for Tripureshwor Leg

Day	Cycle	Recorded At	Length
1	1	9:17:55	207
	2	9:24:59	400
	3	9:35:46	284
	4	9:44:19	220
	5	9:52:09	198
	6	9:58:37	211
	7	10:04:54	215
	8	10:10:32	163
	9	10:15:43	370
2	1	9:04:30	212
	2	9:09:37	228
	3	9:15:33	240
	4	9:20:45	230
	5	9:27:39	323
	6	9:35:03	309
	7	9:44:16	400
	8	9:50:35	206
	9	9:55:13	182
	10	10:02:19	220
3	1	9:34:56	436
	2	9:43:50	444
	3	9:53:25	450
	4	10:02:23	410
	5	10:11:27	384
	6	10:18:48	213
	7	10:26:17	288
4	1	10:00:21	93
	2	10:01:31	202
	3	10:03:45	200
	4	10:07:06	91
	5	10:08:19	74
	6	10:09:14	72
	7	10:09:48	65
	8	10:10:21	67
	9	10:11:07	105
	10	10:12:46	103
	11	10:14:10	127
	12	10:16:14	79
	13	10:18:05	113
	14	10:20:09	132
	15	10:24:22	88
	16	10:25:28	147
	17	10:27:33	98
	18	10:29:47	117
	19	10:31:38	101
	20	10:33:35	124
	21	10:36:46	110
	22	10:38:06	96
	23	10:39:16	115
	24	10:41:20	113
	25	10:44:30	110
	26	10:45:56	91
	27	10:47:18	110
	28	10:49:31	100
	29	10:50:54	77
	30	10:52:07	108
	31	10:56:32	86
	32	10:59:31	82
5	1	9:31:30	375
	2	9:33:23	295
	3	9:35:44	422
	4	9:38:03	462
	5	9:41:05	502
	6	9:43:40	287
	7	9:45:55	303
	8	9:48:06	263
	9	9:49:43	239
	10	9:51:15	215
	11	9:52:41	247
	12	9:54:38	167
	13	9:56:00	159
	14	9:58:02	550

Day	Cycle	Recorded At	Length
	15	10:00:55	271
	16	10:03:42	407
	17	10:06:13	446
	18	10:08:29	295

Day	Cycle	Recorded At	Length
	19	10:10:40	247
	20	10:12:41	223
	21	10:14:12	351
	22	10:18:16	279

Day	Cycle	Recorded At	Length
	23	10:19:37	231
	24	10:22:04	287
	25	10:27:48	399